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THE DEVELOPMENT AND AIRBORNE TESTING OF THE PALE SEAT

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(UNCLA) In this paper I shall describe the development, centrifuge testing and airborne evaluation of the G-protective PALE (Pelvis and Legs Elevating) seat. This articulated seat achieves supination not by reclining the seatback, but by elevating the pelvis and legs forward and upwards, while the head and shoulders barely move. Thus, out-of-the-cockpit vision and vision of displays are unchanged; labyrinthine symptoms are avoided, and head-up displays (HUD) can be easily used because the distance between windshield and eyes does not change. Because no new technological development occurs in a vacuum, I shall review the earlier studies in which transverse (prone or supine) positioning of the pilot had been examined. This historical

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20. review will list and describe all known seat configurations for prone and supine positioning that had reached the stage of the airborne testing. The thankless efforts of these investigators who dared to suggest the use of unconventional seating and who challenged the traditional concepts of aircraft design are documented in tables and photographs. The urgency to provide fighter aircraft with transverse positioned seats can not be over-emphasized at this time. A squadron of aircraft equipped with these seats would have a spectacular advantage in air combat situations, and could literally fly circles around the adversary aircraft.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Flights in Prone Position

(Continued)

Flights in Supine Position

TABLE I (part 1)

CHRONOLOGICAL LISTING OF FLIGHTS IN PRONE POSITION

#	YEAR	AIRCRAFT	COUNTRY	REMARKS	REF	FIGURES #
1	1903	"Wright Flyer"	USA	17 Dec. 1903; Orville and Wilbur Wright; biplane powered by single engine, 12 HP, 2 chaindriven pusher propellers; a/c weight 170 lb; Kitty Hawk, N. C.		
2	1938	FS 17, Experimental High-G Glider	Germany	Load Factor 17 G; designed and constructed by German Glider Research Institute (DFS)	61	2,3,4
3	1941	Horten Ho IVa and IVb	Germany	Tailless glider; Prone couch 60 degree from the vertical, developed by the brothers Reimar and Walter Horten, Maiden Flight: Aug. 41	6, 27-31	5,6,7
4	1942	Horten Ho III-f	Germany	Tailless glider; served for indoctrination in prone flying for more than 20 pilots	6	8
5	1942	Vought XSB2U-3 Vindicator	USA	Prone couch in rear cockpit. Capt USN R. S. Barnaby, Philadelphia Naval Aircraft Factory.	9	9,10,11, 12,13
6	1943	Berlin B9; Experimental low wing cantilever powered by 2 aircooled Hirth HM500, 210 HP	Germany	Load Factor 22 G (!) Expressly Built for High G studies in prone position, which were used in the development of the single prone couch dive bomber Henschel Hs 132 (see #13)	32	14
7	1943	CG-4A and TG-6, Cargo Gliders, modified for prone flying	USA	Towed by P-38; Trainers for prone-flying;**maiden flight of CG-4A by W.F.Sauers,1.Oct 1943; Maiden flight of TG-6 by H.W.Black, 1.Nov.1943.**	10,42	15,16
8	1943	Northrop MX-334; tailless glider	USA	Towed by P-38; Maidenflight 2 Oct 1943. Northrop Test pilot John Myers. Landing speed 100 mph	19,20, 21	17
9	1944	Horten Ho VI	Germany	Maidenflight, in Goettingen, H. Scheidbauer; similar to Horten Ho IV, but superior soaring performance.	6	18
10	1944	Blohm & Voss BV 40	Germany	Fighter/Interceptor glider (armored), Diving speed 560 mph; Towed by Bf 109 G to 23,000 ft in 12 min.	32	19,20,21, 22,23
11	1944	Bachem Ba 349 "Natter"	Germany	VTO Target defense rocket interceptor.	32	24

TABLE I (part 2)

12	1944	Northrop MX-324 "Rocket wing"	USA	Powered by one Aerojet XCAL-200; Maidenflight 5 Jul 1944. Test pilot H. Crosby, Span 36 ft. Thrust 200 lb.	19,20, 21	25
13	1945	Henschel Hs 132 VI Single-prone couch Dive Bomber	Germany	Powered by one BMW 003A-1 axial flow turbojet (1760 lb) mounted above the fuselage.	32	26
14	1945	Northrop XP-79 "Flying Ram"	USA	Powered by two Westinghouse 19 B; Thrust 8760 lb;	37	27
15	1949	High Performance glider "Emouchet" ("Kestrel")	France	Pilot's head supported by chin support. Instruments face forwards. Pilot reads them through a front mirror.		28
16	1949	F-80E and B 17	USA	Nylon net prone couch, **H.T.Hertzberg, R.H.Frost, R.M.Stanley, C.Dempsey**	1,2,22, 26,44	29,30,31 32,33
17	1949	Webee	USA	Beecraft associates, Calif., one of smallest aircraft; wing area 140 ft^2; weight 1650 lb.	2	34
18	1951	Reid and Sigrist R.S.4 Twin engine trainer	U.K.	Prone couch in extended nose. RAF establishment Farnborough. In support of planned rocket interceptor. In design stage in 1951. (Project later cancelled)	2,4	35
19	1952	Horten Alita	Argentina	Span 7.5m; Cordoba. Bipostural hang glider. Could be flown in upright and in prone position.	29	
20	1954	Horten IA 37-P	Argentina	Delta Wing Glider. Maidenflight 1 Oct 1954. **Test pilot in prone position.**	30	36,37
21	1955	Gloster Meteor 8, Twin jet	U.K.	Prone couch in extended nose. Visibility and comfort of prone couch inferior as compaired with couch in F-80E; previous US design (Hertzberg). Project cancelled.	4,22	38,39,40

Introduction

In 1935 Buehrlen of the Aeromedical Research Institute of the German Air Force showed by centrifuge experiments with human volunteers that the tolerance to G loads is significantly higher when the subjects are exposed with their longer axis perpendicular to the G vector, i.e. in prone or in supine position (G_x loads). Buehrlen's work gave the impetus for concerted efforts to position the pilot transverse to the G load. At first, it was the prone position which attracted the interest of the investigators (Fig. 1).

Flights in Prone Position

1. The first Kitty Hawk flights of the Wright Brothers.

For the sake of completeness these flights in prone position should be mentioned here, although the prone position was certainly not adopted to enhance G tolerance in these flights.

2. The High-G Research Glider FS17.

For the first time in the history of aeronautical research a glider aircraft was designed and built to be used exclusively as a test bed for aeromedical studies of G protection; those studies included areas such as visibility, comfort, fatigue, controls and displays, and bail-out capabilities. Anthropometric and comfort studies had been conducted previously with a laboratory mock-up of a prone bed, and such components as adjustable chin and arm rests and other supporting surfaces, as well as control devices and restraint systems had been developed.

The research glider aircraft FS17 was constructed of wood, had a low wing cantilever with a span of 10 meter (∿ 33 ft), and a fuselage length of 5.2 meter (∿ 17 ft). It was fully rated for aerobatic flight and had the remarkable load factor of 14 G (Fig. 2).

The pilot's head was supported by an adjustable energy-absorbing chin rest; the chest rested on the parachute and the lower body was supported by a contoured energy-absorbing couch. Pitch and roll control consisted on a conventional, but shortened and gear-reduced stick. Its upper part included a rotating handgrip which controlled the flaps (Fig. 3). The rudder pedals were replaced by two ladder-type devices with step-in rungs, which allowed operation by pilots who ranged widely in stature. During high G loads, foot movements in the tarso-crural articulation (ankle joint) were sufficient to control the rudder. The restraint harness consisted of five components, which were locked in the pilot's lumbar region but could be easily released in emergencies. The rather long canopy which after jettisoning opened nearly the entire cockpit assured good forward and downward visibility and easy bail-out characteristics. (Fig. 4)

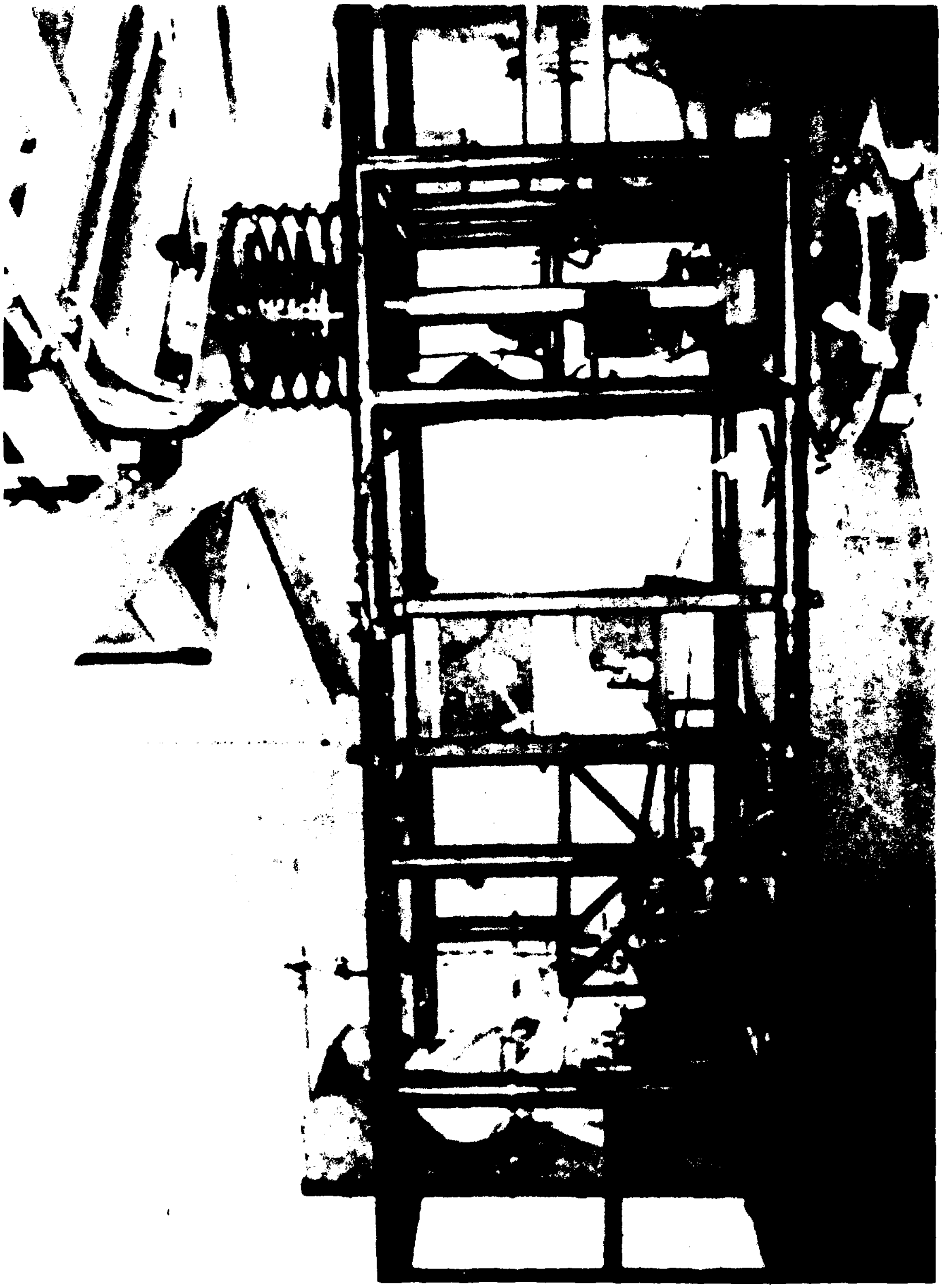


Fig. 1: Human centrifuge at the Aeromedical Research Intitute of the German Airforce in Berlin. Buehrlen (12) used it for his pioneering prone and supine experiments.

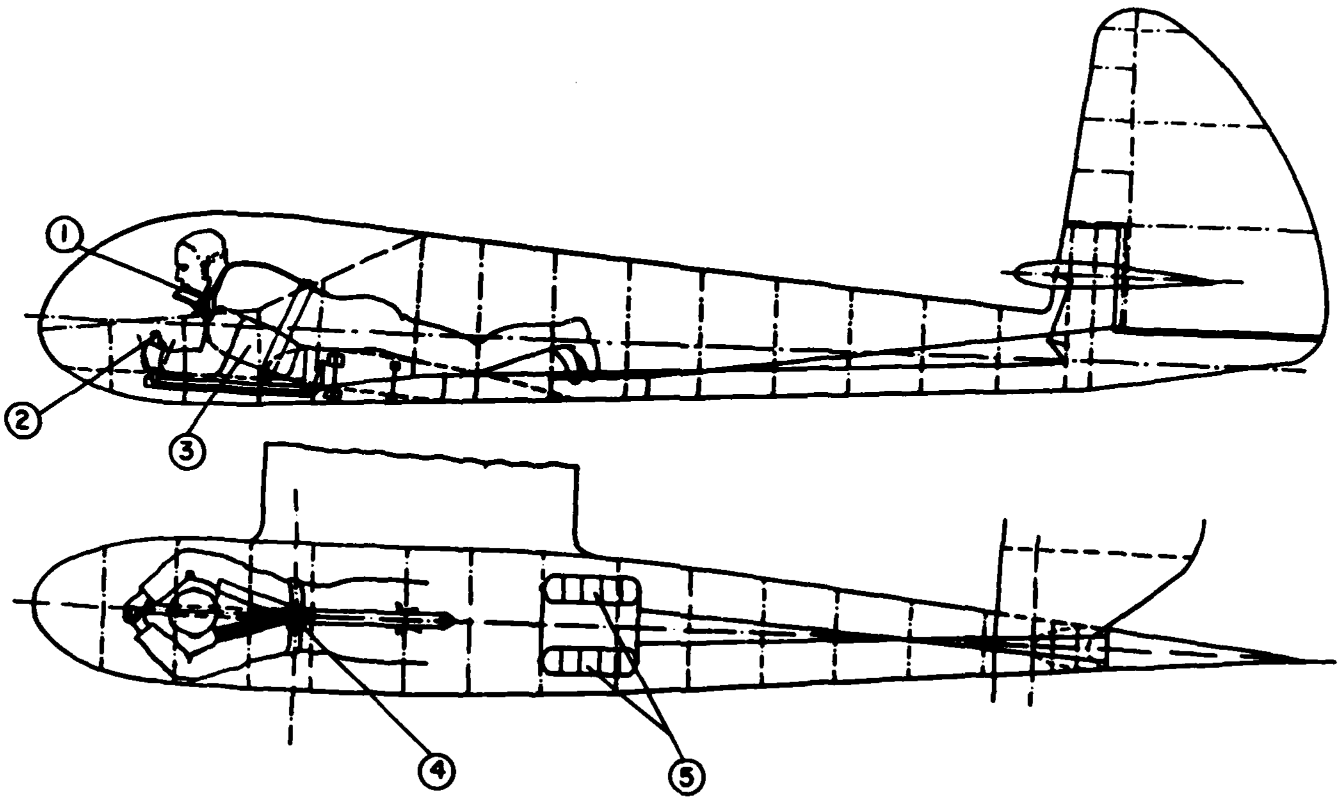


Fig. 2: The High G research Glider aircraft FS 17, with the pilot in prone position, Key: 1 = energy absorbing chin support; 2 = shortened, gear reduced control stick; 3 = parachute; 4 = restraint harness; 5 = ladder-type rudder controls with step-in rungs. From Wiesehoefer (61), 1940.

Fig.3: The cockpit of the High-G research glider FS 17. The canopy is removed. On the top of the control stick is a rotating handgrip, which activated the flaps. From Wiesehoefer (61), 1940.

Fig.4: The pilot occupies the prone couch of the FS 17. An assistant adjusts the restraint harness. From Wiesehoefer (61), 1940.

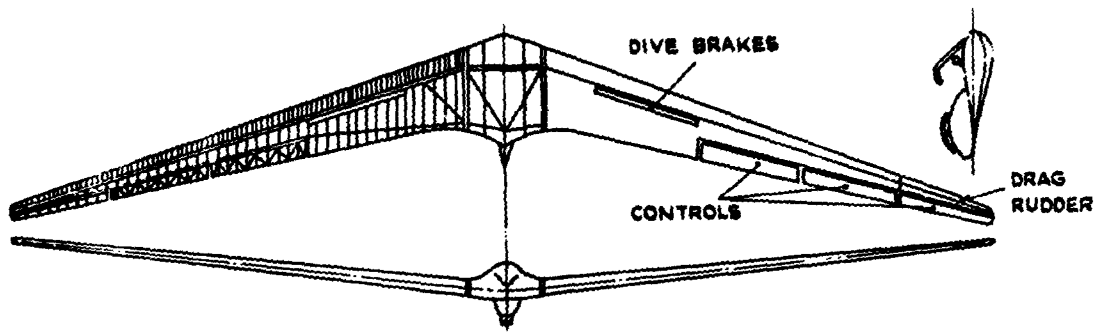
The test flights started in early 1938. In order to generate G loads of longer duration, the pilot at first initiated a dive to increase the glider's speed. Immediately after pull-out, he flew continuous steep turns. High G loads of shorter durations were generated by high speed diving flights and sharp pull-outs. Sustained G loads of up to 8 and 9 G's were routinely tested. In one particular flight the G load reached a peak of 14 G after a sharp pull-out at low altitude. The pilot was not incapacitated and was able to land the FS17 uneventfully, although the leading edge broke off from the spar over the entire wing span. Sustained G loads of 8 to 9 G could be easily tolerated and did not interfere with the subject's flight performance. Soaring flights of durations up to four hours were included in the test program for comfort and fatigue studies.

The test pilots had no complaints about comfort. The visibility forward and downward was judged to be superior to the conventional upright seated position. Sideward and even sideward/backward vision also was satisfactory. Upward and upward/backward vision, however, was very restricted. Obviously, this was considered as a severe handicap for later operational use in fighter aircraft, and the development of several mirror systems was initiated. Other complaints were directed to the fact that the control stick tended to restrict the visual field. Therefore, the incorporation of side-grip controls was initiated. Also, improved restraint systems were developed which assured that during inverted flight or negative accelerations the feet would not loose contact with the step-in rungs. The FS17's counterpart in the powered flight inventory later became the twin-engine, 210 HP, low wing cantilever Berlin B9. (Vide infra).

3. The Tailless Glider Horten Ho IV.

Inspired by the success of the Delta Wing series of the renowned aerodynamicist Alexander Lippisch, the brothers Reimar and Walter Horten, at this time glider pilots in their teens, began in 1930 the construction of their first tailless glider, Horten Ho I. In 1934 this glider won a coveted prize at the classical glider competition at the Rhoen mountains. They followed the novel concept of a "pure flying wing," which aimed to eliminate every source of parasite drag by the suppression of all vertical stabilizing and control surfaces. The pilots cockpit was located within "the flying wing." In order to assure the wing's clean aerodynamic profile, they placed the pilot in supine position in their second construction, the Horten Ho II (May 1935). This aircraft, as well as the supine flights with the Horten Ho V, will be described in the chapter "Flights in supine position." (See also Table II, entries 1, 2, 3).

Beginning in 1941, the Horten brothers preferred the prone position. The Horten Ho IV was a tailless glider with a span of 20 m.(∿ 66 ft) and the very high aspect ratio of 23.16; its sinking speed was 0.54 m/s (∿ 1.77 f.p.s.) and the empty weight 200 kg (∿ 440 lb). It was at these times considered the world's best high performance sail plane. The prone couch was inclined at an angle of 60 degrees (from the vertical). The pilot had the knees bent which were supported by energy absorbing knee cushions. (Fig. 5, 6, 7).



HORTEN IV

SPAN	20·0 m (65·6 ft)
AREA	18·9 m^2 (203 ft^2)
ASPECT RATIO	23·16
WEIGHT, EMPTY	200 kg. (440 lb)
WEIGHT, LOADED	300 kg. (660 lb)
WING LOADING	15·87 kg./m^2 (3·5 lb/ft^2)
GLIDING ANGLE	37·0°
SINKING SPEED	0·54 m/s (1·77 f.p.s.)

Fig. 5: Diagram of the tailless glider Horten Ho IV

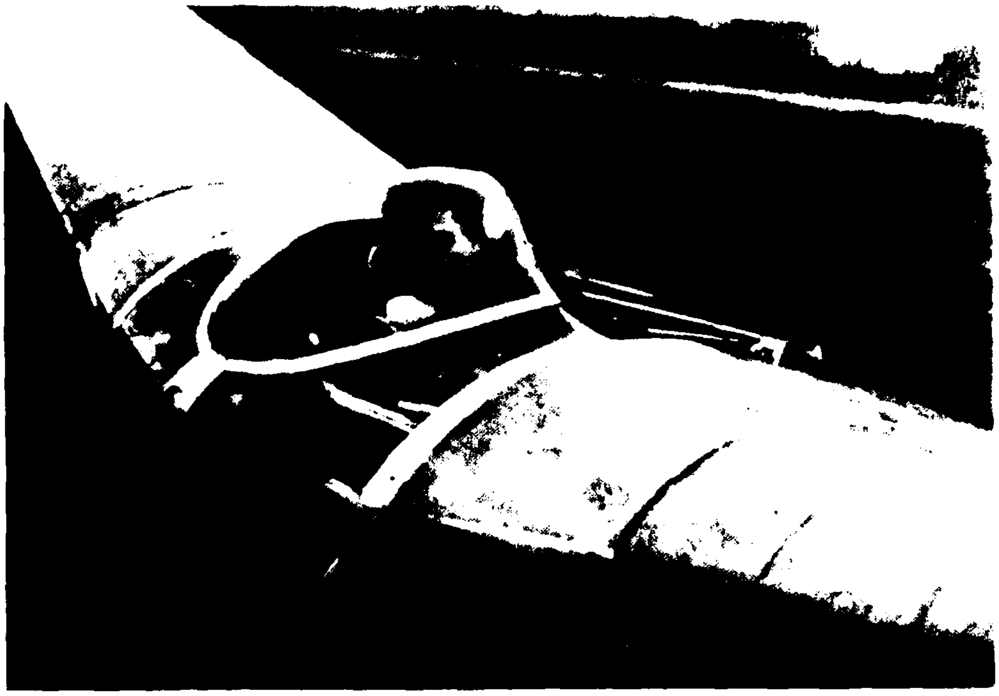


Fig. 6: The Horten Ho IV conducted by R. Opitz in the USA

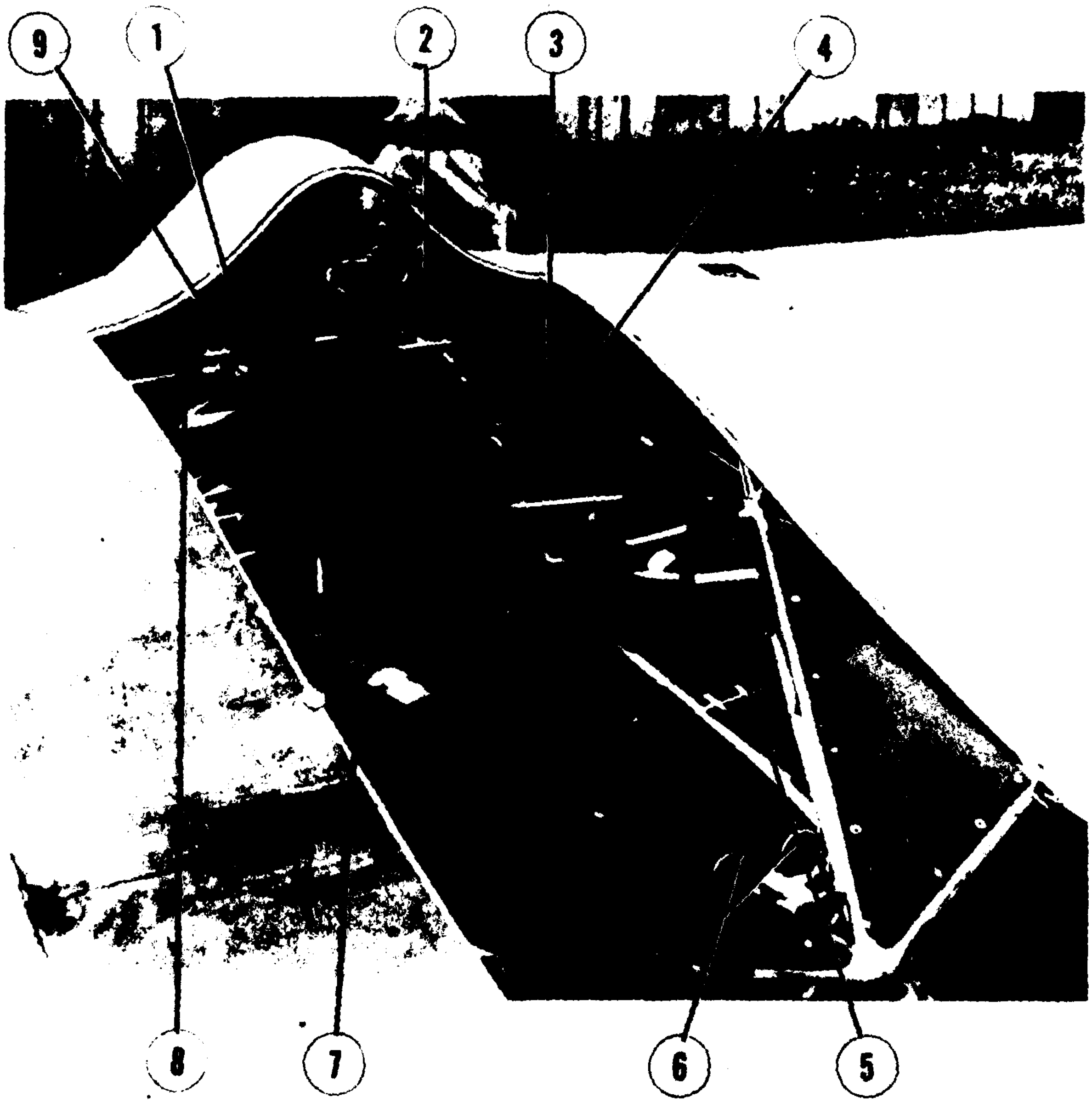


Fig. 7: Oblique rear view of cockpit of the Flying Wing Glider Horten Ho IV. Key: 1 = left instrument panel; 2: Control lever for retractable skid and for jettisoning the dolly; 3 = support for right arm; 4 = prone couch which supports the pilot in a half kneeling, half lying posture, not unlike a praying mantis; 5 = barograph; 6 = adjustable control pedals; 7 = oxygen bottle; 8 = left horn of bimanual control column; 9 = ring for disengaging the tow hitch. Behind 9 (*not visible*): Control lever for diving brakes.

Thus, he was half kneeling and half lying. This position, not unlike that of a "praying mantis", was considered to be comfortable by the pilots. Several thousand hours had been flown in this aircraft, including flights of 10 hours duration and instrument flights through clouds. Both the knee supports and the chin support could be adjusted; the latter could be adjusted during flight.

4. The Horten Ho III-f.

Because of the increasing interest in prone flying, a flight trainer became necessary. In 1942 the Horten brothers installed in a Ho III, (Fig. 8) which had been flown since 1938 in a conventional but reclining, position, a "praying mantis" type prone couch. This modified Ho III became known as the Horten Ho III-f. More than 20 pilots had been checked out for prone flying with this aircraft.

5. The Vought SB2U-3 "Vindicator".

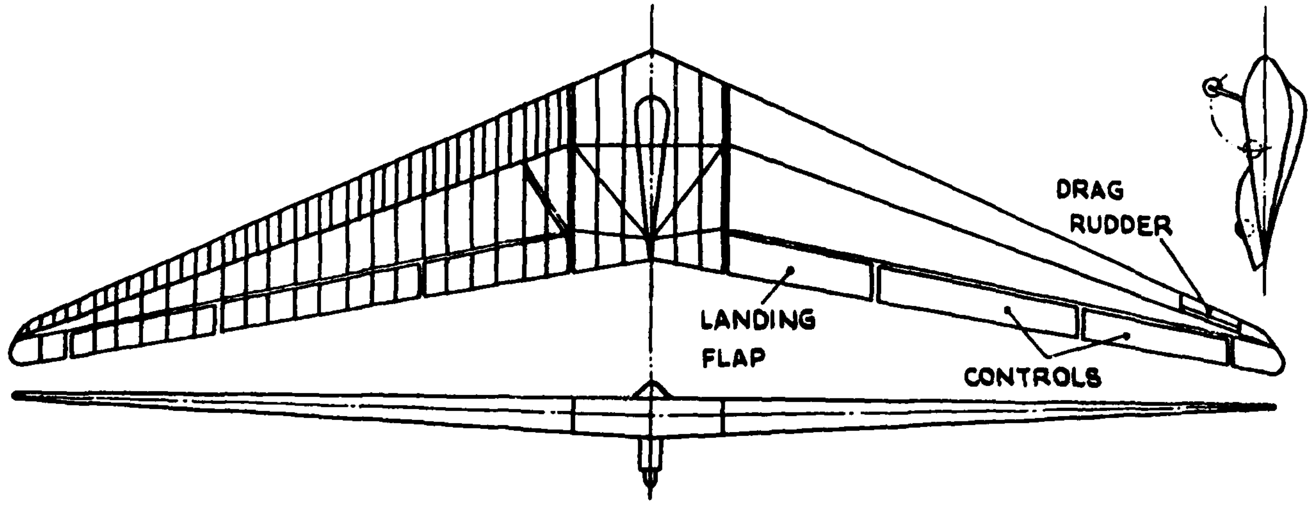
In 1942 Ralph S. Barnaby of the Naval Aircraft Factory in Philadelphia had installed a prone couch in the second cockpit (Fig. 9), of a SB2U-3 "Vindicator" bomber (Fig. 10). The couch consisted of a fixed portion that supported the trunk, and movable jointed links that supported and moved with the legs. The fixed portion was recessed to take a chest mounted parachute and included chest supports which were adjustable in the vertical direction. The head was maintained in the desired position by a rigid chin support (Fig. 11), which could be adjusted horizontally and vertically, or by a chin sling (Fig. 12) hanging from an overhead structure. The installation of the rudders is shown in Fig. 13. In his prone position, Barnaby, on several occasions, showed that he could remain functional while the control pilot, seated upright in the first cockpit was blacked out.

6. The High-G twin engine Research aircraft Berlin B9.

This counterpart to the High-G glider FS17 in the powered flight inventory was developed by the Aeronautical Research Group of the Technological University of Berlin and later was officially designated the 8-341. Only one prototype was manufactured (Fig. 14). It had the unusual load factor of 22 G. Based upon the experiences with the FS17, several improvements were incorporated and successfully tested. One of those was the use of mirror systems which improved the upward/backward vision and also made several displays located in the rear part of the cockpit visible for the pilot. The 8-341 was ultimately used to gather data for the development of advanced aircraft. The gathered data was amply used for the design of the Henschel Hs 132, a ground attack diving aircraft with a prone couch (See Table I, entry 13).

7. The Gliders CG-4A and TG-6.

In 1943 the Aircraft Laboratory at Wright Field conducted intense efforts to provide cargo gliders with prone position controls. The service cargo glider CG-4A with prone position flight controls was flown on 1 April 1943 by W. F. Sauers, accompanied by a Safety Pilot and an Observer (42). The test pilot's report criticized the controls because of the high forces necessary to actuate the ailerons and the rudders, and because of the frequent jamming of elevator controls resulting from unsatisfactory bearings. The test pilot



HORTEN III

SPAN	20·0 m (65·6 ft.)
AREA	37·5 m^2 (403 ft^2)
ASPECT RATIO	10·66
WEIGHT, EMPTY	250 kg. (550 lb.)
WEIGHT, LOADED	350 kg. (770 lb.)
WING LOADING	9·33 kg./m^2 (1·91 lb./$ft.^2$)
GLIDING ANGLE	28·0°
SINKING SPEED	0·65 m/s (2·13 f.p.s.)

Fig. 8: Diagram of the Horten Ho III

Fig. 9: The Vought SB2U-3 "Vindicator" before modification with Prone Couch.

Fig. 10: The "Vindicator" with Prone Couch installed

Fig.11: The "Vindicator" with Captain USN Ralph S.Barnaby in Prone Position

Fig.12: Same as Fig.11, but the chin support is replaced by a sling head support

Fig.13: Rear part of the cockpit of the "Vindicator", showing the rudder installation

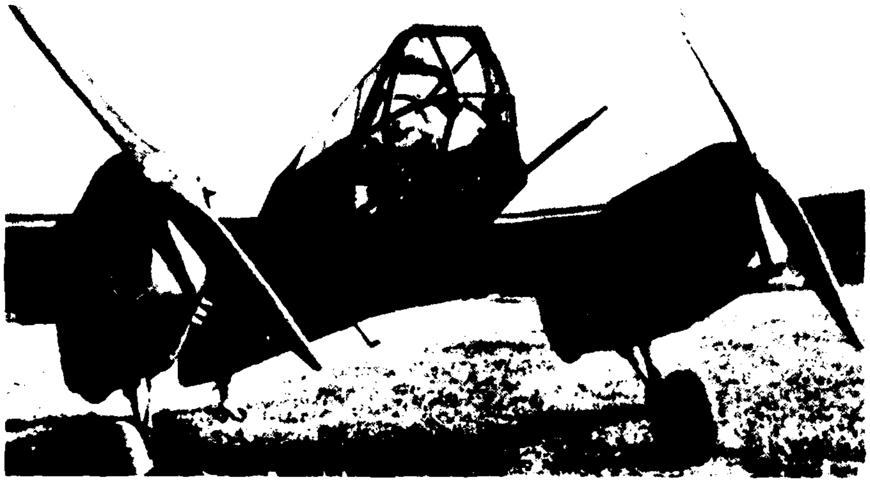


Fig. 14: The High G twin-engine research aircraft Berlin B 9. It was powered by two inverted engines Hirth HM 500 of 105 HP. It had the unusual load factor of 22 G (!). From Kens et al. (32),1961

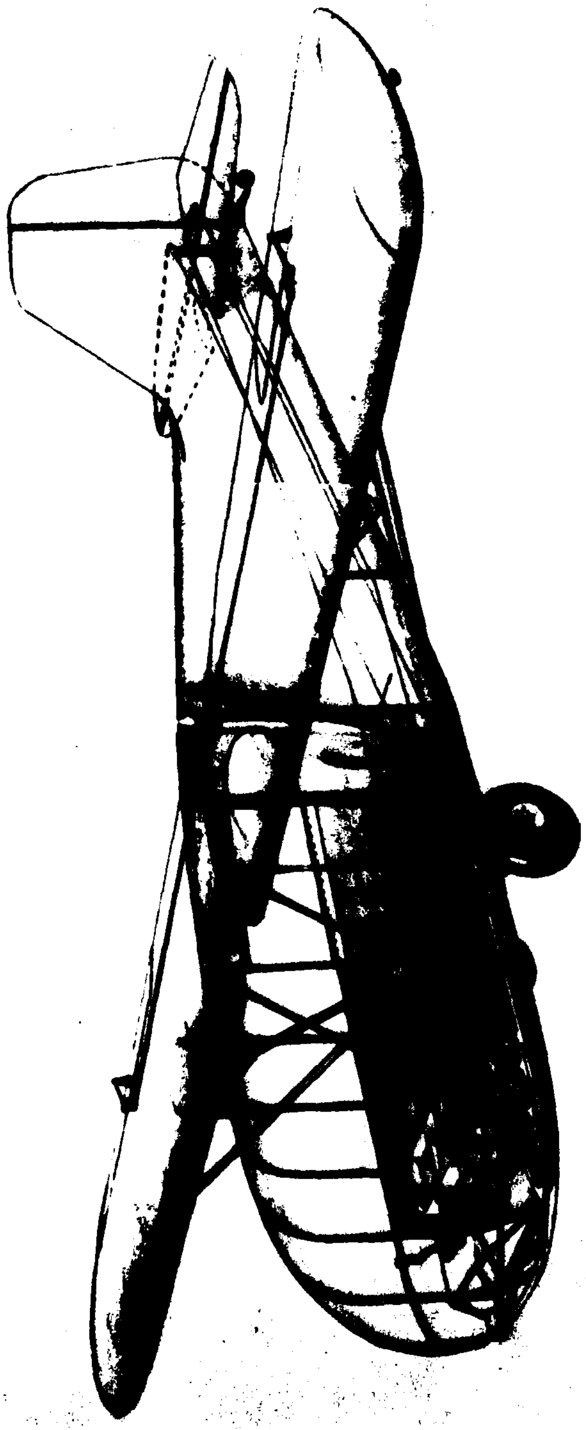


Fig.15: The Cargo Glider TG-6 modified for prone flying

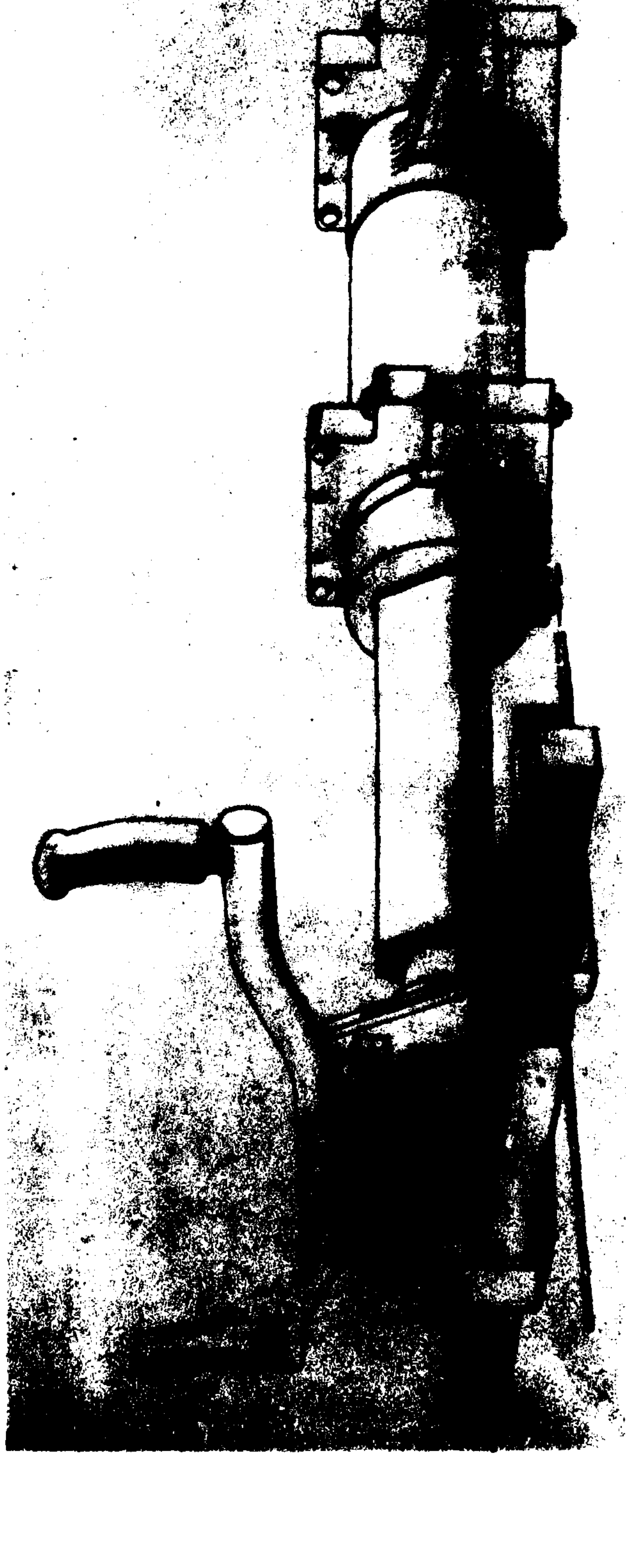


Fig. 16: Prone controls used in the Cargo glider TG-6

also complained about fatigue due to the high control pressures and the difficulty of "looking around." Interesting enough, he also believed that "there is a greater tendency to air sickness while flying from the prone position." In summary, his report declared the CG-4A unsatisfactory as a prone position control transitional trainer.

Later in 1943, the testing of a novel unconventional prone control system installed in the Trainer glider TG-6 (Fig. 15) was reported by H. W. Black (10).

The unconventional control system (Fig. 16) allowed control of elevator, rudder and ailerons with hands alone. Pushing forward or backwards with both hands moved the control column and actuated the elevators. Pressure forward with one hand, and relaxation of pressure by the other, moved the cross arm about its axis and controlled the rudder; downward pressure on the cross arm with one hand and upward pressure with the other hand, rotated the control column and moved the ailerons. Based upon more than 30 test flights, the main complaints centered around the fact that both hands were needed to operate the elevator, aileron and rudder controls. It was impossible to make a turn using only one hand, because back pressure on only one side of the cross arm actuated both the rudder and elevator. Also the spoilers could not be used for the final approach before landing because they were also hand operated. The same was true for auxiliary devices such as radio knobs, microphone switches, etc. Other critical comments referred to the couch angle which was considered to low and which was suggested to be increased to 30 degrees (from the horizontal), unsatisfactory padding, and head support. It is interesting to add that the test glider was picked up successfully 5 times using a Model 15 Pick-up unit as installed in the Liason aircraft L-1A.

8. The Northrop Flying Wing MX-334.

The Northrop Corporation had already constructed in 1939 the N-I-M, the first US manufactured flying wing. In this aircraft the pilot was seated in the conventional upright position.

The flying wing MX-334, in which the pilot was in prone position (Fig.17), was completed in 1943. The control surfaces were unconventional. Pitch and roll control was obtained by the use of "elevons" and yaw was controlled by inboard surfaces termed "brudders." The limit of diving speed was 478 mph true air speed at sea level and 516 mph at 30,000 ft. Towed by a P-38, the maiden flight was piloted by Northrop test pilot J. Myers on 2 Oct 1943 (19). The test pilot expressed great satisfaction in the flight, but stated that the brudders did not create enough yaw, especially at low speeds near the stalling point. The elevons, however, gave adequate lateral and longitudinal control. At this time the Army Air Force Materiel Command (20) studied the feasibility of installing an Aerojet power unit in one of the three MX-334 gliders. (Vide infra)

Fig. 17: Mock-up of the Flying Wing Northrop MX-334 with the pilot in Prone Position

9. The Tailless Glider Horten Ho VI.

The Horten Ho VI (Fig. 18) was very similar to the Ho IV but was superior in its performance. The span was 24 m ($\sim$ 79 ft.), i.e. 4 m more than the Ho IV, which resulted in a higher aspect ratio of 32.4 and the more favorable sinking speed of only 0.43 m/s.

The pilot was located on a prone couch identical to the one of the Ho IV (type "praying mantis"). Only two Ho VI were built. They served especially for Sailing Record flights (1944).

10. The Glider Fighter/Interceptor Blohm und Voss BV 40.

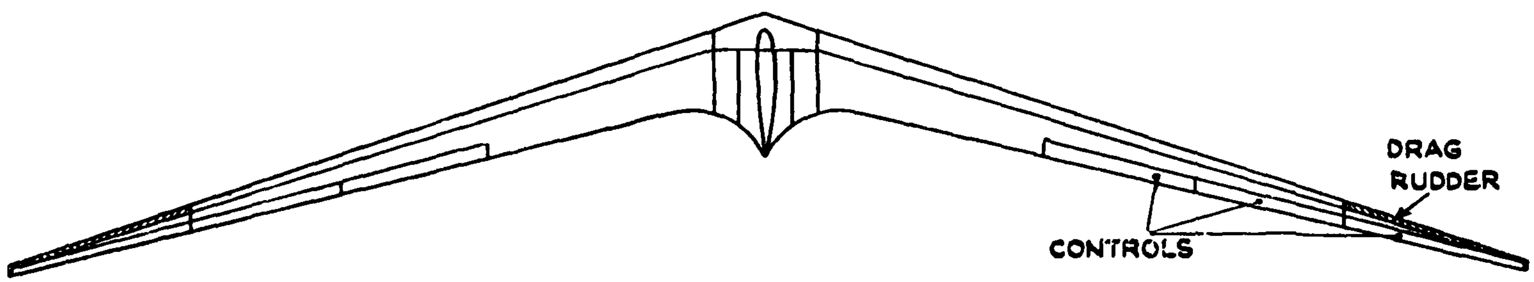
The BV 40 was one of the most unorthodox designs of aeronautical history. The rationale for its prone design was not only G protection for the pilot, but rather to create an interceptor aircraft with a very reduced frontal area which would assure that - attacking hostile bomber formations - it would be in head-on attack virtually invisible for the bomber's gunners before it actually opened fire. Obviously, there were only two means to decrease the frontal area significantly: (1) to place the pilot in transverse (prone) position; (2) to eliminate the engine, since especially radial engines-such as the one of the Focke-Wulf FW 190 - increased the frontal area substantially. The result of these considerations, was one of the most unorthodox gliders ever constructed (Fig. 18-22).

It was a heavily armored, single prone-couch glider interceptor-fighter, with a maximum diving speed of 900 km/h ($\sim$ 560 mph). It could be towed to an altitude of 7,000 meters ($\sim$ 23,000 ft) by a Messerschmitt Bf 109 G in 12 minutes. A two-wheel trolley, jettisoned immediately after the aircraft became airborne, served for the take off. It landed on an extendable landing skid (Fig. 19).

Using mostly non-strategic materials (Fig. 20-23), the cockpit was constructed of welded sheet metal, the front panels being of 20 mm ($\sim$ 0.8 in.), the side panels and jettisonable roof of 8 mm ($\sim$ 0.32 in.) and the floor of 5 mm ($\sim$ 0.2 in.) thickness. The protection of the pilot's head was accomplished by a windshield of 120 mm ($\sim$ 4.7 in.) armored glass and two sliding armor panels, which could seal off the side windows. The armament consisted of two 30 mm ($\sim$ 1.18 in.) automatic cannons of the type MK 108. Between May 1944 and September 1944 seven prototypes became airborne and the basic flight program had been completed. In September 1944, however, before any operational use of the BV 40 could be considered, the program was halted due to higher priorities.

11. The V. T. O. Target Defense Rocket Interceptor Bachem Ba 349.

Another, equally unorthodox project, was the vertical rocket interceptor Bachem Ba 349, better known as "Natter" (Fig. 24). It is interesting to note that a vertically launched, rocket-powered, target-defense interceptor had been designed and proposed by Wernher von Braun as early as 1939, but was considered by the responsible authorities as too "unrealistic" and therefore tabled.



HORTEN VI

SPAN	24·0 m. (78·7 ft.)
AREA	17·8 m^2 (191 ft^2)
ASPECT RATIO	32·4
WEIGHT, EMPTY	250 kg. (550 lb.)
WEIGHT, LOADED	350 kg. (770 lb.)
WING LOADING	19·68 kg./m^2 (4·0 lb/ft^2)
GLIDING ANGLE	
SINKING SPEED	0.43 m/s

Fig.18: Diagram of the tailless glider Horten Ho VI

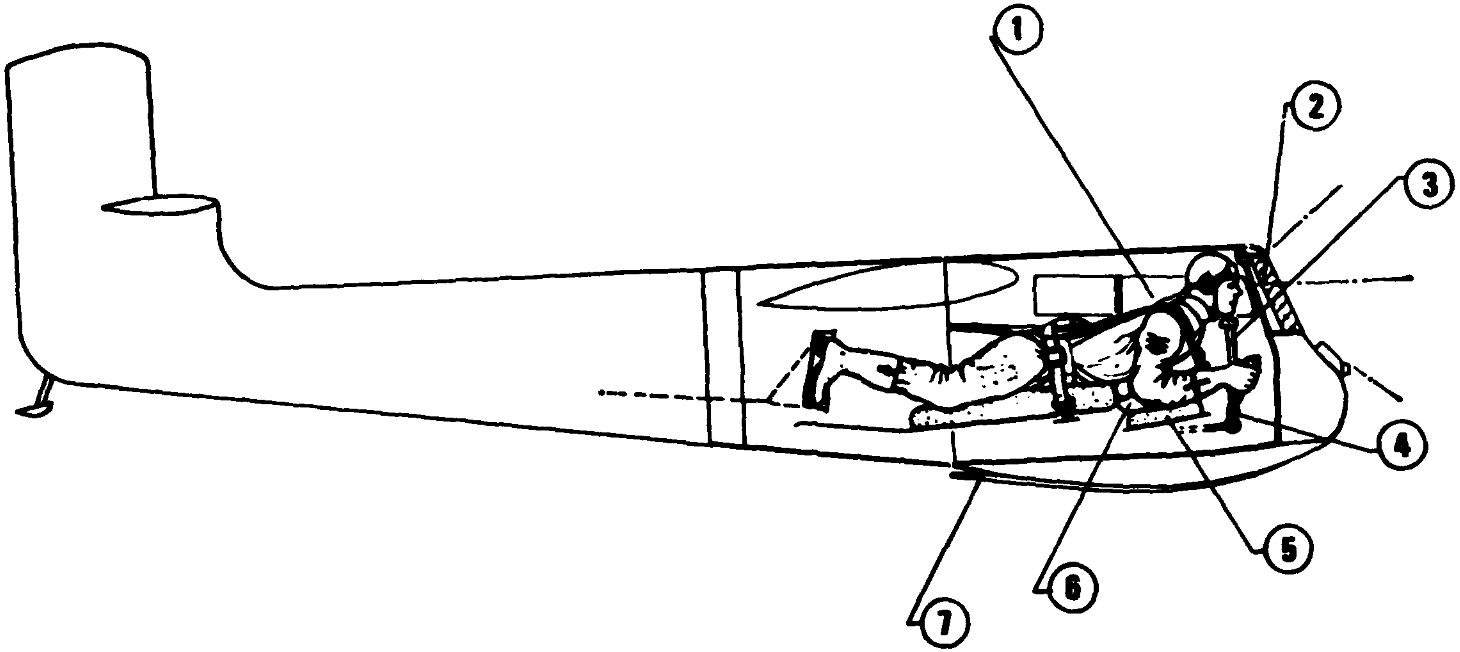


Fig.19: The glider fighter/interceptor Blohm und Voss BV 40. This heavily armored glider could reach diving speeds of 560 mph. Key: 1 = sliding armor panel, which could seal off the side windows; 2 = windshield of 4.7 in. armor glass; 3 = pivoted, energy absorbing chin support; 4 = control stick; 5 = armrest; 6 = parachute; 7 = extendible landing skid. From Kens et al. (32), 1961.

Fig.20: Side view of BV 40

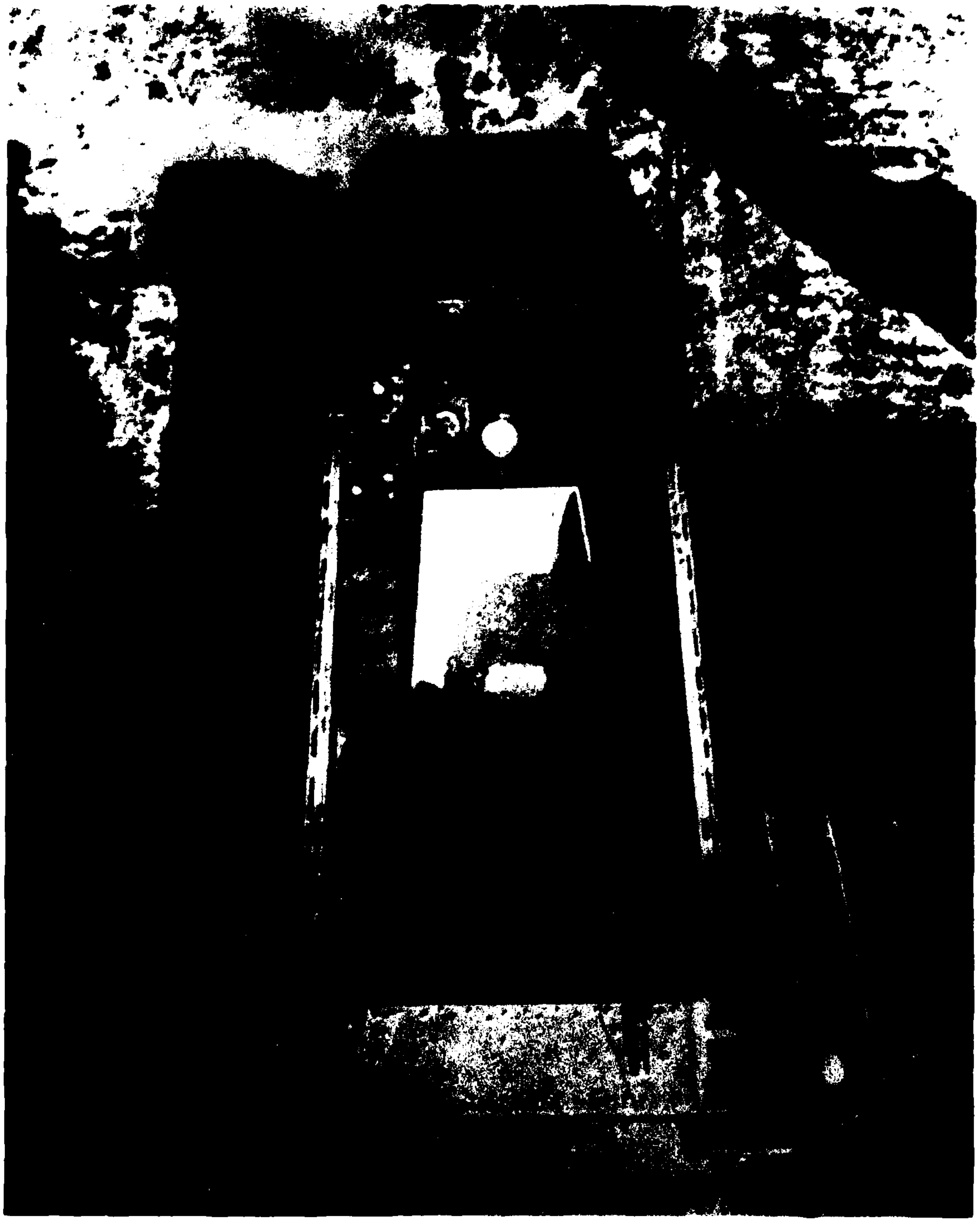


Fig.21: Oblique View of BV-40. Rearwards of the Instrument Panel is the tray for the chest parachute.

Fig.22: Structures of the cabin floor of the BV 40.

Fig.23: Rear of prone couch and rudder pedals of the BV 40

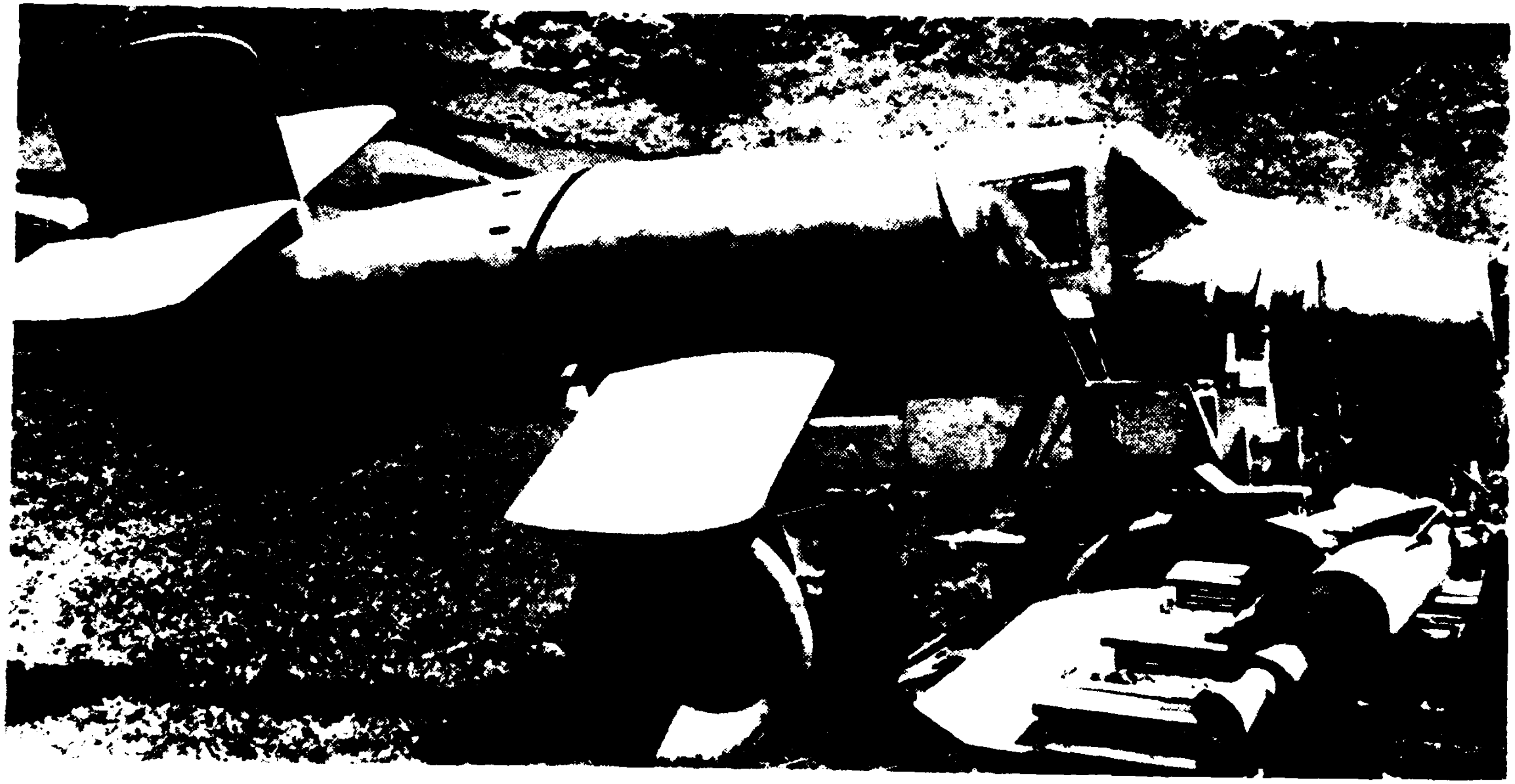


Fig. 24: The VTO Target defense rocket interceptor Bachem Ba 349 "Natter". The "Natter" (engl: Viper) was a semi-expendable midwing cantilever powered by a Walter rocket engine of 4,500 lb thrust. In the foreground is one of the four take-off assisting solid fuel rockets Schmidding 109-533, which developed together a thrust of 11,500 lb. From Kens et al.(32), 1961.

In 1944, however, this concept was revived within the "Fighter Emergency Program". Since at this time hostile bomber formations had rather short approach routes, the requirement existed to develop an interceptor which was able to take off when the hostile formation was already in the range of vision and to be able to intercept it before it reached the target area. The Ba 349 was a semi-expendable midwing cantilever rocket interceptor which was launched from a near vertical ramp. It was powered by a Walter 509 D 2000 kg ($\sim$ 4500 lb) thrust rocket motor. The vertical take-off was assisted by four 1200 kg ($\sim$ 2,650 lb) thrust solid-fuel booster rockets. After 10 seconds burning time the booster rockets were jettisoned and a ground controlled auto pilot took control of the craft. At a range of approximately 2 - 3 km ($\sim$ 1.3 - 1.9 miles) from the target formation, it was planned that the pilot would override the autopilot control and, after closing in, fire a salvo of the nose cone housed rocket missiles. Afterwards, the nose separated and the pilot and the stern of the craft were recovered by two independent parachute systems.

In the preliminary design configurations the pilot was located in prone position in order to maintain the slim aerodynamic profile of this "manned missile". The lack of backward vision was not believed to be a disadvantage.

In order to train prospective pilots of the "Natter" in prone flying the two seat tandem glider DFS Kranich 2W, was modified by the installation of a prone couch and widely used for training. This training program, however, became obsolete, when it was decided that the final configuration of the "Natter" allowed the location of the pilot in conventional position. This was believed to be more favorable for the control (including fire control) of the craft. It also posed less problems for the separation of nose and stern, and for the parachute recovery.

Between December 1944 and the end of the hostilities 25 Ba 349 underwent airborne testing; seven of those were manned and 18 were pilotless test flights. The "Natter" came rather near to operational use: In a last ditch effort in April 1945, 10 Ba 349 were placed on ramps in the Stuttgart area awaiting the incursion of bomber formations. The advance of hostile ground forces, however, made their destruction mandatory, before they could be operationally used.

12. The Northrop MX-324 "Rocket Wing".

U.S. Intelligence was aware of German rocket aircraft developments, which had already at the beginning of WW II reached the stage of airborne testing. Thus, it was Northrop's aim, to power his flying wing MX-334 with a rocket propulsion unit which became later known as the MX-324 "Rocket Wing". A contract for this construction was let by the U.S. Army Air Force in October 1943. A static stress test restricted the allowable accelerations to + 8 g and to - 5.33 g (21). With the cooperation of the Aerojet Engineering Corporation the rocket motor XCAL-200 was installed, which had a weight of only 427 lb.

Fig.25: The Northrop MX 324 "Rocket Wing"

Since the rocket motor developed a thrust of only 200 lb, the MX-324 had to be towed to altitude by a Lockheed twin engined P-38 fighter. The Maiden flight took place in strict secrecy on July 5, 1944, at Harper Dry Lake, in the Mohave Desert. The Northrop Test Pilot H. Crosby released the tow line at 8000 feet altitude and activated the rocket engine. After a flight of 5 minutes, which consumed 31 gallons of fuel, Crosby landed smoothly on the dry lake bed. The manufacture and the flights of the "Rocket Wing" were maintained secret until early in 1947. The MX-324 is considered the first U.S. rocket-powered airplane and the first prone cockpit aircraft for the USAAF. (This is correct, because the prone cockpit of the Vought XSB2U-3, developed and flown by Captain USN R. S. Barnaby in 1942, was sponsored by the Bureau of Aeronautics of the U.S. Navy).

It is interesting to note that only three weeks after the MX-324 maiden flight, on July 28, 1944, eight P-51D Mustang pilots flying escort for a B-17 fortress formation encountered for the first time five rocket fighters Me163-B in the vicinity of Merseburg (near Leipzig).

Impressed by their very dense white contrails and their speed, which they judged to be between 500 and 600 mph, they reported the encounter in detail to the HQs of the U.S. 8th Air Force, which caused considerable concern. The Officer commanding the fighter element of the 8th Air Force, Major General W. Kepner dispatched immediately a message to all groups indicating instructions how to meet the new threat. His concern would have been much less if he would have known that the Luftwaffe had accepted delivery of only 16 production Me163-B interceptors.

13. <u>The dive bomber and ground attack aircraft Henschel Hs 132</u>.

Based upon testflights with the Berlin B9 (Vide supra), the Henschel Flugzeugwerke (aircraft factory) decided early in 1944 to provide their new fast, turbojet dive bomber and ground attack aircraft with prone controls (Fig. 26). It was powered by one BMW 003A-1 axial flow turbojet rated at 1,760 lb., which was mounted above the fuselage, exhausting over the rear fuselage and between the twin vertical surfaces of the tail assembly. Its span was 23 ft., length 29 ft, and wing area 159 sq. ft..

14. <u>Northrop XP-79 "Flying Ram"</u>.

Northrop brought the prone position to use again in their short lived prototype XP-79 "Flying ram". The wings were built of heavy magnesium plate to withstand the ramming blows. It was powered by 2 Westinghouse 19 B jet engines. Its wingspan was 38 feet, the weight 8670 lb (Fig. 27). The first airplane of its type ever built, it was intended to dive on enemy bombers, slicing off tail assemblies to down them. The pilot was in prone position in order to raise his "blackout threshold". The XP-79 could fly at a top speed in excess of 500 mph.

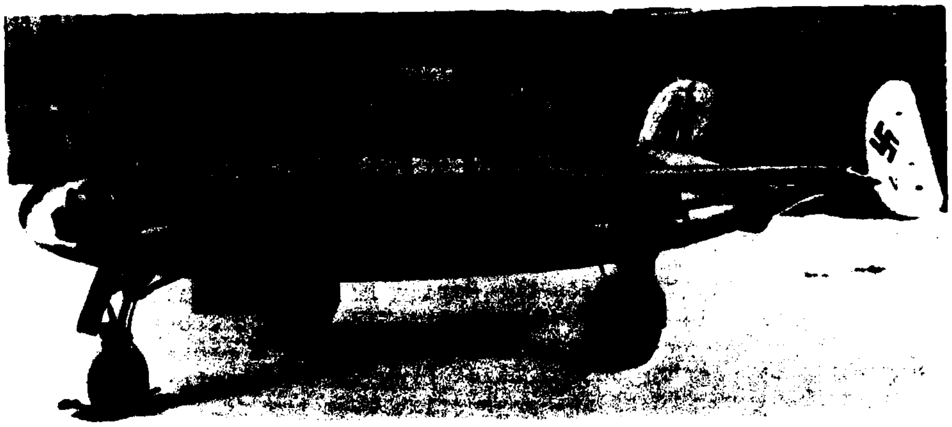


Fig. 26: The Dive Bomber Henschel Hs 132 with the pilot in prone position

Fig.27: The Northrop XP 79 "Flying Ram" with the pilot in prone position

15. <u>The High Performance Glider "Emouchet"</u>.

The Centre d' essais du Vol (Test Center of the French Air Force) at Bretigny conducted prone positioning comfort studies in support of a planned high altitude reconnaissance aircraft which was designed for prone control in order to maintain a favorable airfoil. This effort, however, was discontinued before the prone assembly was airborne tested. A glider aircraft, however, the "Emouchet" was flown in 1949 in prone position (Fig. 28). The instruments can be seen below the subject's chin rest and were visible for the pilot by a mirror system.

16. <u>The Lockheed F-80E and the Boeing B-17</u>.

Since one of the major criticisms against the prone position was discomfort during prolonged missions, special efforts were directed to develop an optimally supporting structure. In 1948 H. T. Hertzberg (26), of the Anthropometric Unit of the Aeromedical Research Laboratory at Wright Patterson AFB developed a novel prone bed consisting of a nylon hamock net with an adjustable jaw rest, a counterweighed head support, and an adjustable foot rest. In addition, special armrests were integral with the airplane controls (Fig. 31, 32, 33). These controls were based on the three dimensional system developed by H. H. Amtmann (1), and allowed for alternate right or left single handed control (Fig. 30). The prone couch, and the three dimensional control system were incorporated in the extended nose of a F-80E and for long duration testing in the B-17 (Fig. 29 & Fig. 32). The Stanley Aviation Corporation then of Buffalo NY, had the responsibility for this modification of the nose of the F-80E, and for the subsequent test flights. Their report is most informative (44):

"During the safety pilot's taxying, take-off, and climb to altitude, visibility and control/movement were checked, and about 5,000 ft altitude, the prone pilot took over control of the aircraft..."

"Forward and downward visibility was, of course, superb, and lateral visibility seemed adequate, but rearward and upward vision was very restricted and was particularly noticeable in steep turns, where it was impossible to see more than an estimated 30° ahead of the aircraft..."

"The prone bed was perfectly comfortable..."

"In summary, it is this pilot's opinion that the prone pilot control installation is satisfactory. With brakes, flap and dive brake controls installed, and another hour of familiarization flight involving acrobatics, no hesitation would be felt in attempting take-offs and landings."

In October 1950 an article from Fritz and Heinz Haber entitled "Possible Methods of Producing the Gravity-free state for Medical Research", appeared in the Journal of Aviation Medicine. This paper described how a restricted time of weightlessness could be obtained by flying a vertical ballistic parabola. **In the wake of the Habers' paper, a flurry of zero-gravity experiments was begun in both the northern and southern hemispheres (i.e. in both the United States and Argentina),**

Fig.28: The French High Performance Glider Emouchet (French for Kestrel)

Fig.29: The modified F 80-E. In the extended nose is the prone couch.

Fig.30: Amtmann's prone control(1) was used in the F-80E

Fig.31: A nylon-net prone couch was developed by Hertzberg (26) for the F-80E and B-17.

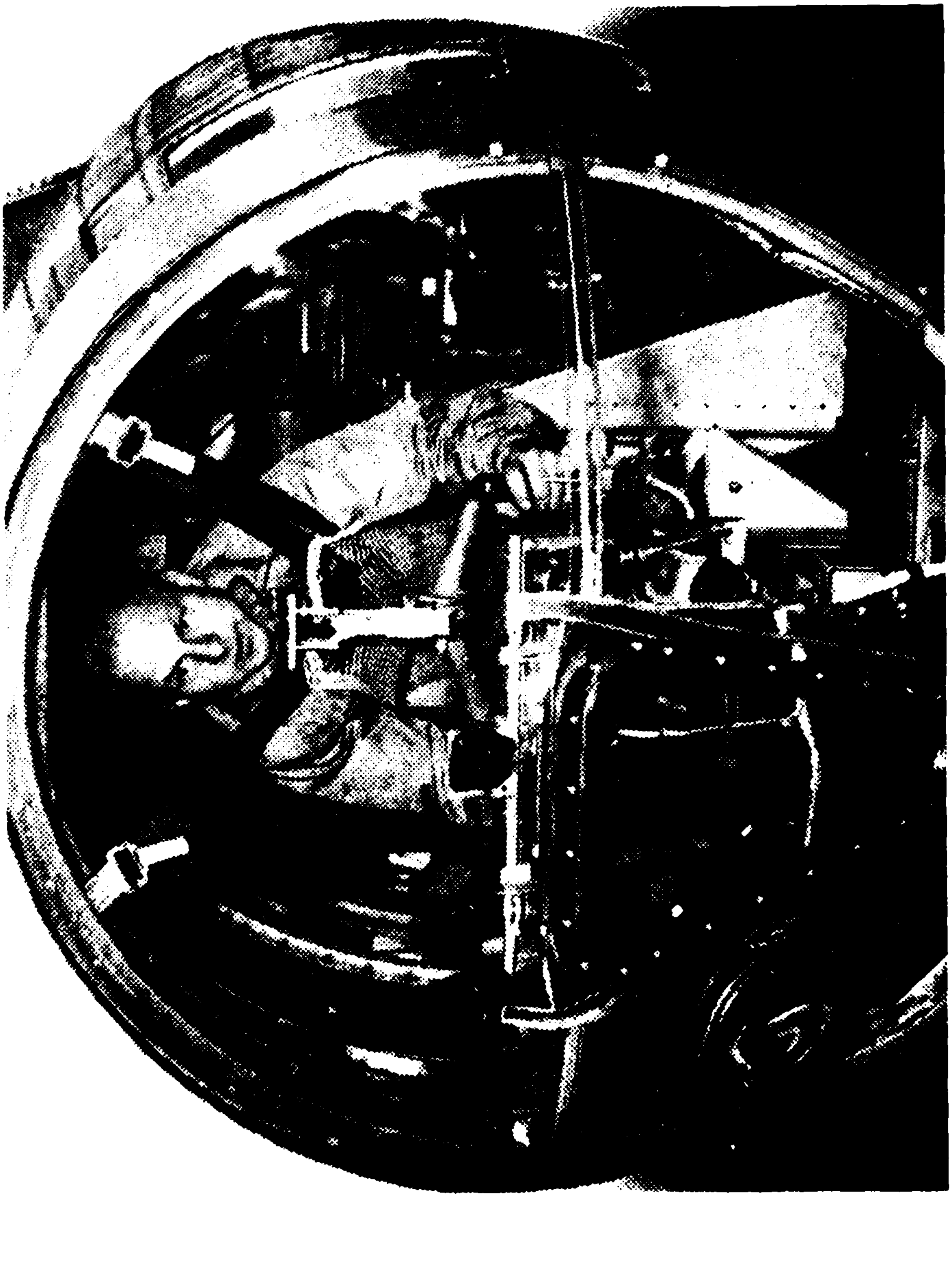


Fig.32: Subject on nylon-net prone couch in B-17 mock-up

Fig.33: Rear part of nylon-net couch and rudder pedals

In 1952, the paper "Human Experiments in Sub-gravity and Prolonged Acceleration" by E. R. Ballinger appeared in the Journal of Aviation Medicine. The flights were hastily done in the summer of 1951. The author reported that during each flight, the subject was given eight to ten sub-gravity runs that averaged 15 seconds duration. The longest zero-gravity run lasted slightly over 20 seconds.

The F-80E aircraft was selected for these studies and the report elicited considerable curiosity among its readers who wondered why an aircraft with prone controls was used for the zero-gravity experiments. In fact, the F-80E was selected simply because it was available at that time. Thus we can now understand why the F-80E is known in the world literature not as an aircraft with prone controls, but as the first zero-gravity vehicle of the United States.

17. The Webee.

Also one of the smallest known aircraft, the Webee should be mentioned here (Fig. 34) since the pilot flew in a prone position. It was thought that this aircraft would be useful for the indoctrination in prone flying.

18. The Reid and Sigrist R.S.4.

In 1951, the RAF undertook a program to provide a novel planned rocket-powered interceptor with prone controls. The Royal Aircraft Establishment in Farnborough modified the twin-engine trainer Reid & Sigrist R.S.4 by extending the nose and incorporating a prone bed and controls (Fig. 35). The prone bed was articulated, permitting separate alignment of each section of the chassis accomodating independent attitudes of the trunk, thighs and lower legs. Also, the length of the thigh and lower leg chassis was variable. The pilot controlled these adjustments by electric actuators. The controls were located ahead of the pilot's chin rest (Fig. 39). There were no dual hand grip controls, but rather one control column located towards the right side.

19. The Horten Alita.

The Horten brothers, who worked after WW II in the Aerotechnical Institute of the Argentine Air Force completed in 1952 the Horten Alita, a biopostural Hang glider, which could be flown in the upright hanging position as well as in the prone position (Alita in Spanish: Little Wing).

20. The Horten IA-37-P.

Somewhat later, in 1954 the Horten brothers completed a more sophisticated project, the delta wing glider Horten IA-37-P which made its maiden flight with R. Horten at the controls in prone position (29) (Fig. 36 and Fig. 37). Later productions could be flown in conventional position. In many flights the take-off could be made by catapult.

Fig.34: The light aircraft WEEBEE manufactured by Beecraft Associates for indoctrination in prone flying.

Fig.35: The British twin engine trainer Reid and Sigrist RS-4 modified for prone flying. The prone couch is in the extended nose.

Fig.36: The Argentine Flying Wing Horten IA 37-P.
Reimar Horten enters the prone cockpit.

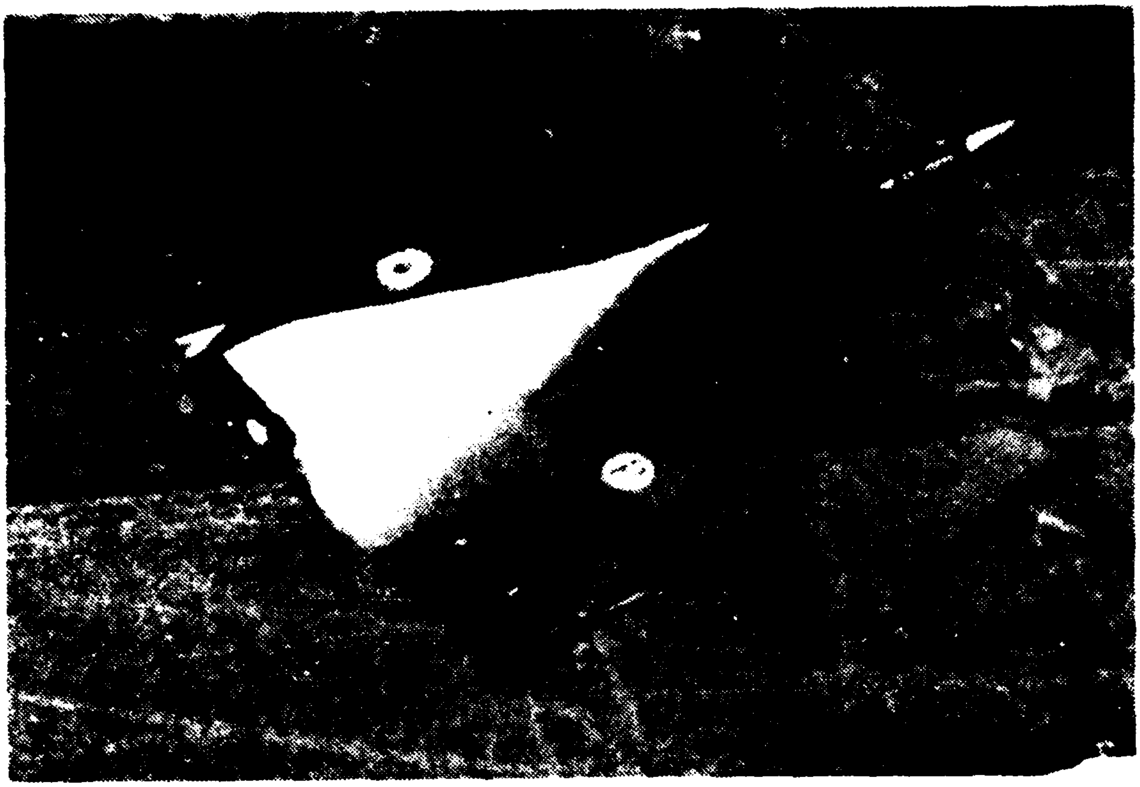


Fig.37: The Horten IA 37-P in flight over Argentina

21. The Gloster-Meteor 8.

The assembly described for the R.S.4 was also flown in the extended nose of a modified Gloster Meteor 8 (4). As expected, the test subject could easily tolerate G loads up to 6.5 G. At this level, however, the experiments had to be discontinued because the structural limit of the Meteor 8 had been reached (Fig. 38, 39, 40). The fact that the development of the rocket powered interceptor was discontinued also put an end to the prone positioning experiments.

Fig.38: The Twinjet Gloster Meteor 8 with the prone couch in the extended nose

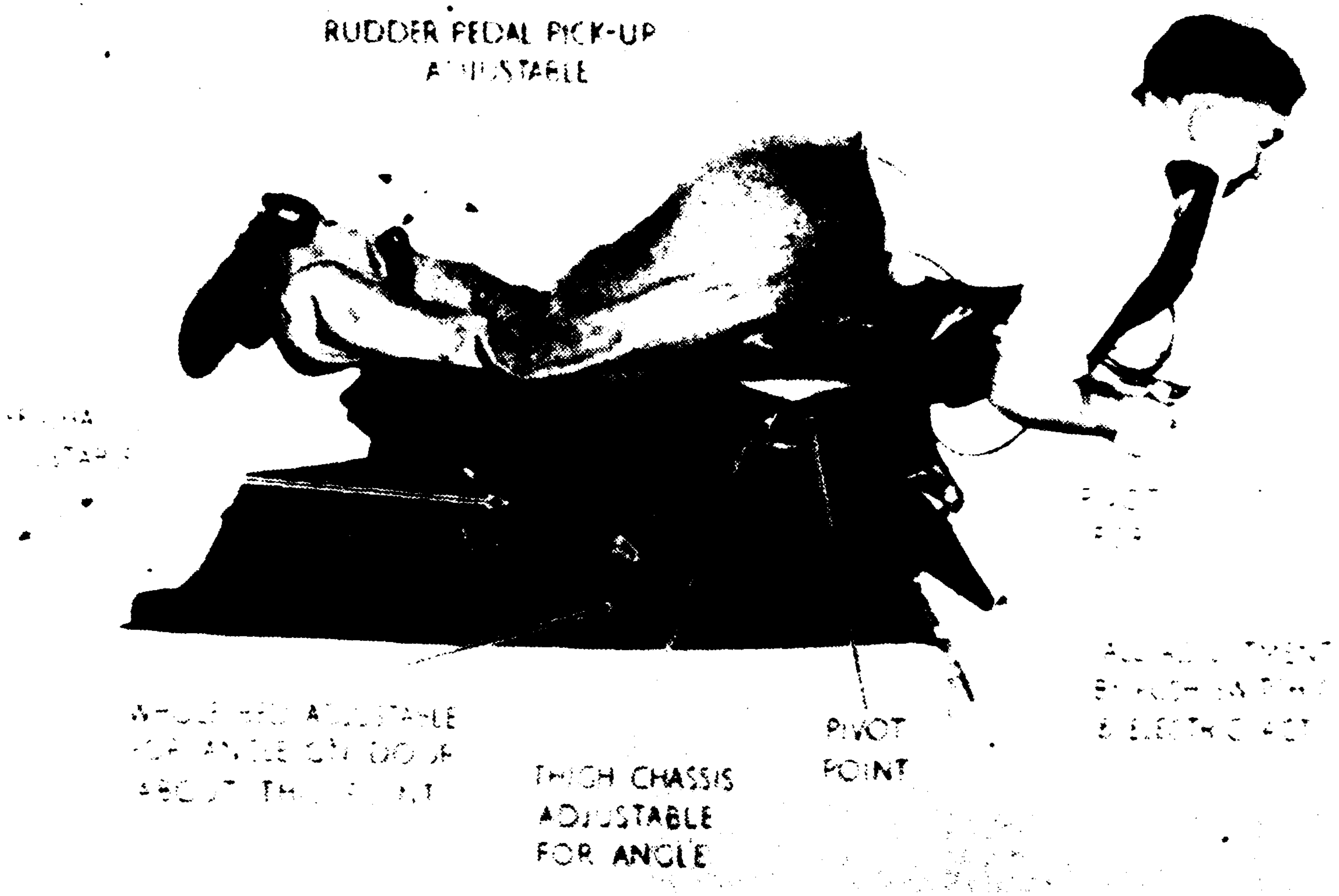


Fig.39: The prone couch developed by the Royal Air Force and flown in the Gloster Meteor 8.

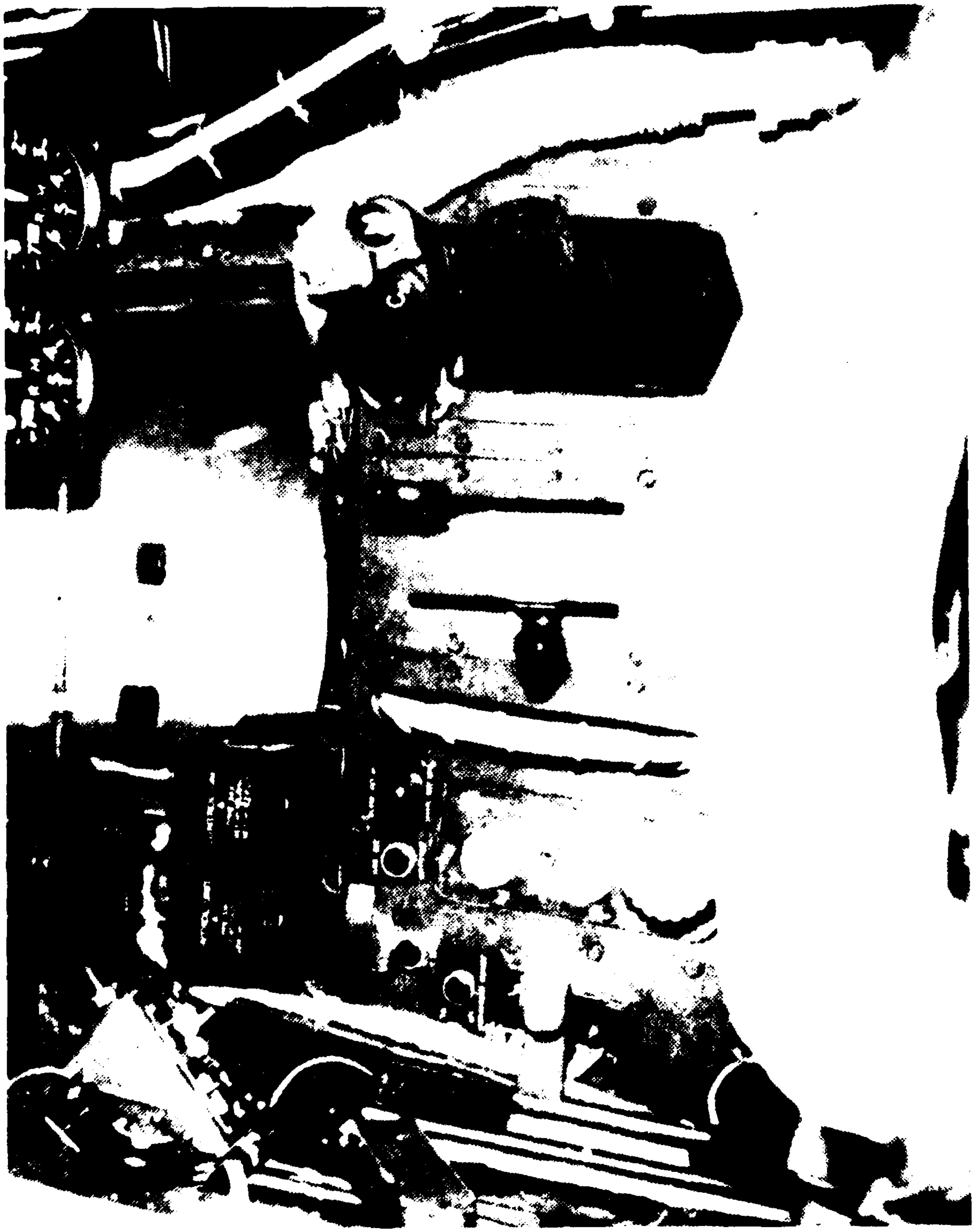


Fig.40: Instrument Panel and Controls in the anterior part of the prone cabin of the Gloster Meteor 8. The control column is to the right.At the top center is the transparent flooring.At the bottom is the chin rest.

TABLE II (part 1)

CHRONOLOGICAL LISTING OF FLIGHTS IN SUPINE POSITION

#	YEAR	AIRCRAFT	COUNTRY	REMARKS	REF	FIGURE
1	1935	Horten Ho II, Tailless glider	Germany	"Pure flying wing", i.e. no vertical stabilizing or control surfaces. Pilot in supine position. Vertical distance from seatpan to canopy roof: 0.7 m (~ 2.3 ft). Bent control stick like in now-a-day high performance gliders. Maidenflight May 1935 (R. Horten). First Glider Flight in Supine Position.	3, 6, 30	41
2	1936	Horten Ho II - M, Motor glider	Germany	Same as above, but powered by one air-cooled engine Hirth HM 60R, 80 HP submerged in wing; pusher airscrew. Maiden flight Feb 1936 (R. Horten). *First Powered Flight in Supine Position.*	6, 31	41
3	1937	Horten Ho V, Twin engine motor glider	Germany	Powered by two Hirth HM 60R, 80 HP, air-cooled engines. Two pilots side by side in supine position. Maiden flight: 2 June 1937 (R. and W. Horten).	6, 27	42, 43
4	1938	Heinkel He 50 and Junkers Ju 87	Germany	Supinating tilting seats developed by the German Experimental Institute of Aeronautics (DVL); S. Ruff, H. Wiesenhoefer, K. Stoeckel. Maidenflight of He 50 in Fall 1938.	61	45, 46, 47, 48, 49
5	1940	Fairey Battle K-9289 Light bomber	U.K.	W. K. Stewart, RAF Physiology Laboratory, modified the seat in the rear cockpit so as to support a wood mock-up with a seat angle of 45 to 50 degrees (from the vertical). The author desired to reach a more favorable reduction of the hydrostatic levels by a seatback angle of 65 degrees, but structural limitations of the a/c did not allow it.	45	50, 51

FLIGHTS IN SUPINE POSITION

TABLE II (part 2)

6	1951	Grumman F7F-2N "Tigercat", Twin engine Marine Night Fighter a/c	USA	C. F. Gell of the Naval Air Development Center (NADC) installed a reclining seat in the elevated rear cockpit. Evaluation at the Naval Test Center, Patuxent River, was negative. Test pilots objected to the impairment of out-of-the-cockpit vision and poor visibility of displays (parallax).	24	52, 53, 54, 55, 56
7	1979	Sikorsky CH 53-A	USA	"PALE" (Pelvis and Legs Elevating) Seat; H. J. von Beckh, NADC. Supination accomplished not by reclining the seatback, but by elevating the pelvis and legs forward-upward, while the head barely moves. Out-of-the-cockpit vision and visibility of displays unchanged. Labyrinthine symptoms avoided. 1971 - 1977: Development and centrifuge evaluation with 20 subjects up to 14 G for 45 seconds without visual impairment. 20 April 1979: Airborne evaluation at NADC satisfactory.	51, 52, 53, 54, 55, 56, 57, 58	57, 58, 59, 60, 61, 62, 63, 64

Flights in Supine Position

1. The Tailless Glider Horten Ho II

The spectacular success of the brothers Reimar and Walter Horten was already mentioned in the chapter describing flights in the prone position (30).

Already in their second construction of a tailless glider, the Horten Ho II, they placed the pilot within the "flying wing" in a supine position (Fig. 41). The vertical distance from the seat pan to the canopy roof was barely 0.7 m ($\sim$2.3 ft). Similar to modern high performance gliders, the control column was bent in the form of a knee, so that it was within the reach of the reclined pilot. The maiden flight was made in May 1935 with Reimar Horten at the controls. This must be considered as the first glider flight in the supine position.

2. The Horten Ho II-M

In February 1936 they provided the Horten Ho II with an air-cooled engine, an 80 HP Hirth HM 60R, which was submerged in the wing and drove a pusher airscrew through an extension shaft. The Maiden flight was made by Reimar Horten in February 1936, and this flight was the first flight in the supine position with a motor aircraft (6).

3. The Twin Engine Tailless Wing Horten Ho V

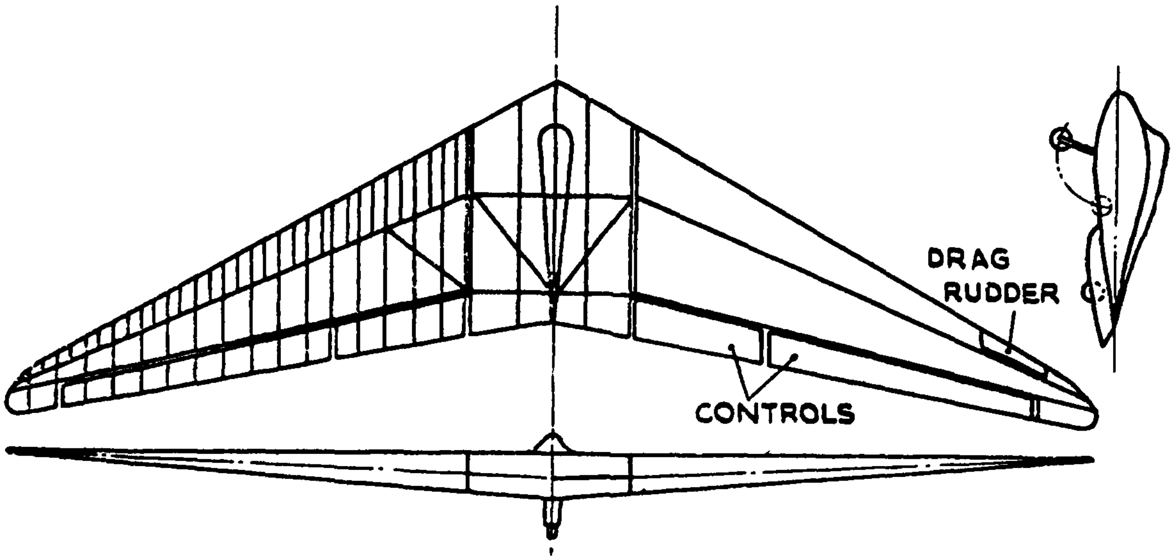
This was the first Horten aircraft intended from the outset for powered flight. Unlike the Horten II-M, not one, but two Hirth HM 60R engines were buried within the wing and drove pusher airscrews by means of extension shafts (6). The maiden flight was on 2 June 1937 with both Reimar and Walter Horten lying side-by-side supine at the controls (Fig. 42 and 43).

Between 1937 and 1945 the Horten brothers developed numerous tailless aircraft (27), including the most unorthodox tailless Turbojet Fighter Bomber Horten Ho IX (Fig. 44).

Others, like the Horten Ho III, Ho IV, and Ho VI were flown in the prone position and are described in part I.

4. The Supinating Seat of Wiesehoefer in the Heinkel He 50

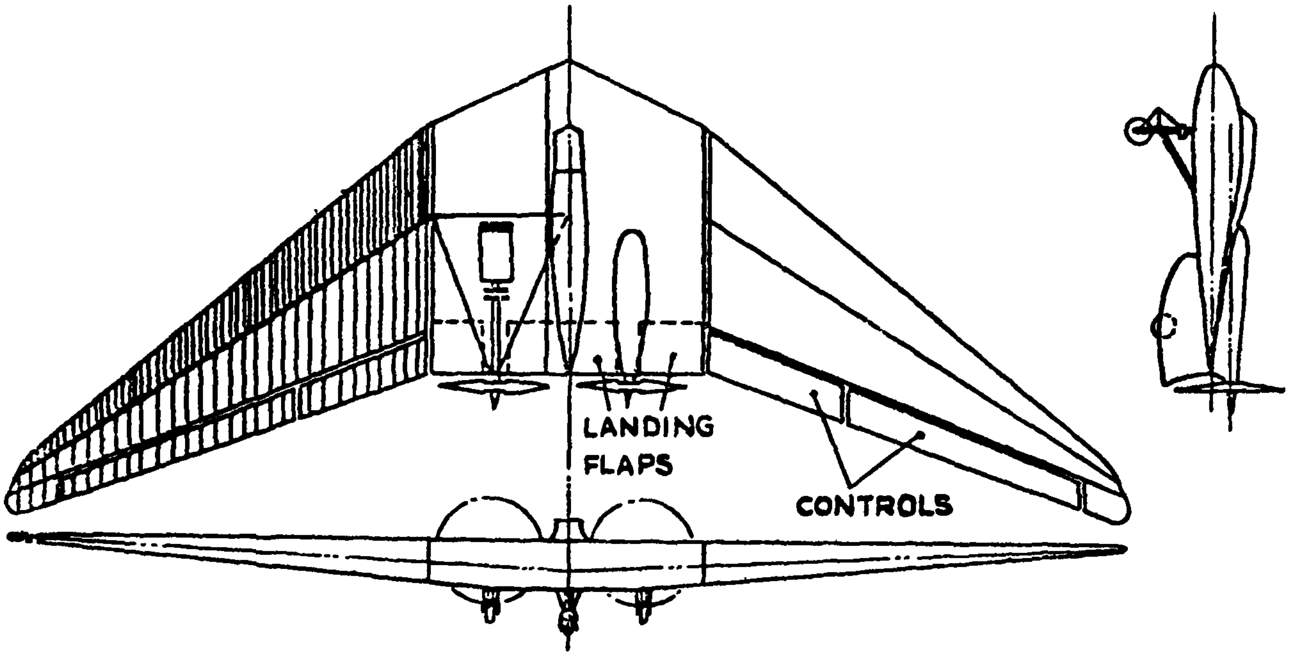
The previously cited centrifuge experiments of Buehrlen (12,13) influenced the Institute of Aviation Medicine of the German Experimental Institute of Aeronautics in Berlin-Adlershof to conduct research with supine seats.



HORTEN II

SPAN	16·5m (54·1 ft.)
AREA	$32{\cdot}0m^2 (34{\cdot}4 ft.^2)$
ASPECT RATIO:	8·48
WEIGHT, EMPTY	275 kg (606 lb)
WEIGHT, LOADED	375 kg (827 lb)
WING LOADING	$11{\cdot}38 kg/m^2 (2{\cdot}33 lb/ft^2)$
GLIDING ANGLE	24·0°
SINKING SPEED	0·80 m/s (2·62 f.p.s.)

Fig.41: Diagram of the tailless glider Horten Ho II. Reimar Horten made the Maiden flight in supine position in May 1935. Later the Ho II was provided with a 80 HP motor and renamed the Ho II-M. The Maidenflight was again made by Reimar Horten in February 1936. These two flights must be considered as the first glider flight and the first powered flight in the supine position.



HORTEN V

SPAN	16·0 m. (52·5 ft.)
AREA	42·0 m^2 (451 ft^2)
ASPECT RATIO	6·1
WEIGHT, EMPTY	1050 kg. (2310 lb)
WEIGHT, LOADED	1250 kg. (2760 lb)
WING LOADING	29·8 kg/m^2 (6·1 lb/ft.^{2})
MAXIMUM SPEED	215 km/hr (134 m.p.h.)
LANDING SPEED	75 km/hr (47 m.p.h.)

Fig.42: Diagram of the tailless motor glider Horten Ho V. This aircraft was powered by two Hirth HM 60R of 80 HP each. The maiden flight was on 2 June 1937 with both Reimar and Walter Horten laying side-by-side at the controls

Fig.43: The tailless motor glider Horten Ho V in flight

Fig.44: The tailless Turbojet Fighter Bomber Horten Ho IX

H. Wiesenhoefer (61), of this organization, recognized that the continuous supine position achieves protection only against radial G loads, but leaves the pilot unprotected against linear loads in the direction of the flight path, which are especially high in catapult take-offs and in arrested landings.

Therefore, he constructed a seat which is normally in the conventional position, but which adopts the supine position when high radial accelerations are acting.

This seat, also called the "Flop back seat", is depicted in Fig. 45 and 46. The seatback could be tilted backwards/downwards, until a horizontal body position was reached; at the same time, the seat itself moved forward. The seat-back was maintained in the conventional position by two spiral springs and a locking device. The latter was disengaged automatically whenever the G load reached the value of $+3G_z$. Two shock absorbers provided adequate damping when the supine position was reached. With the decay of the accelerations the two above-mentioned spiral springs pulled the seat-back again in the conventional position where it was automatically locked.

The G loads were recorded on an accelerograph which was synchronized with a recording device that indicated the tilting motion of the seat (Fig. 47).

This seat was installed in the second cockpit of an older model biplane dive bomber (Heinkel He 50) and was flight tested in the fall of 1938 (Fig. 48). In 16 missions, each containing 3-5 acceleration periods, 5 subjects were exposed to $+G_x$ loads up to 15-seconds duration. The supinated subjects experienced acceleration peaks up to $+7G_x$. As is usual in airborne acceleration exper ments, the pilot at first initiated a dive to increase the aircraft's speed. Immediately after pull-out he flew continuous steep turns. Giving up altitude during these turns helped in maintaining and quantifying the desired accelerations. These maneuvers were later termed "Diving Spirals". During the high G loads the normally seated pilot had to fly in a "crouch" position and had to work to increase his G tolerance by straining and repeated M-1 maneuvers.

The purpose of these test flights was only to show that the tilting seat functioned properly under airborne conditions. The subjects had no controls with which to steer the aircraft. However, controls were provided in a later configuration made by Stoeckel and built in the dive bomber Junkers Ju 87 (Fig. 49). In spite of the successful flight testing of this seat, no further development ensued. This was because the High Command de-emphasized the efforts of protective aircrew positioning. At the time when the various prone and supine positioning systems could have been considered for operational use, the only aircraft capable of producing excessive G-loads, the Ju 87, was already obsolete as a dive bomber because of its low horizontal speed (300 km/h $\sim$ 190 mph) and, therefore, easy interceptability. As a matter of fact, during the last years of World War II the Ju 87 was almost exclusively employed in low level ground support missions, mostly against hostile armor. The other craft of the air inventory had no load factors which would have made increased G protection of the crew necessary. Thus, the absence of a real need as well as the ever-present resistance of the engineering community to depart from the conventional position and control systems were the causes that these developments did not reach operational use.

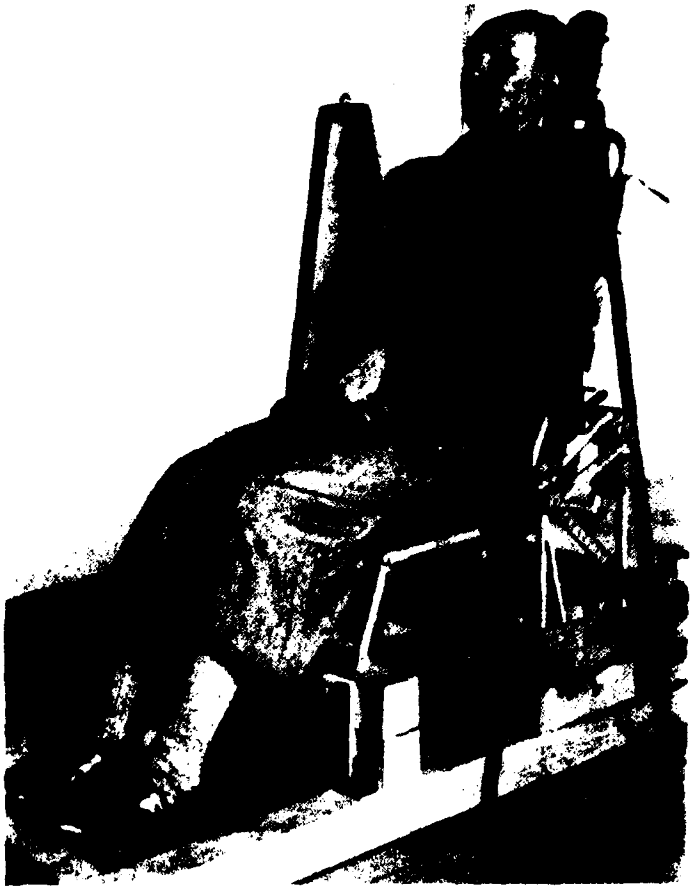


Fig. 45: Laboratory Model of the tilting aircraft seat DVL-1, also called "Flop Back Seat". The two spiral springs on both sides of the seat maintain the seat in the upright position where it is locked by a spring loaded device. Whenever the G load reaches 3 G (with some deviation corresponding to the weight of the subject) the lock disengages automatically and the seatback descends to a horizontal position. From Wiesehoefer (61), 1940.

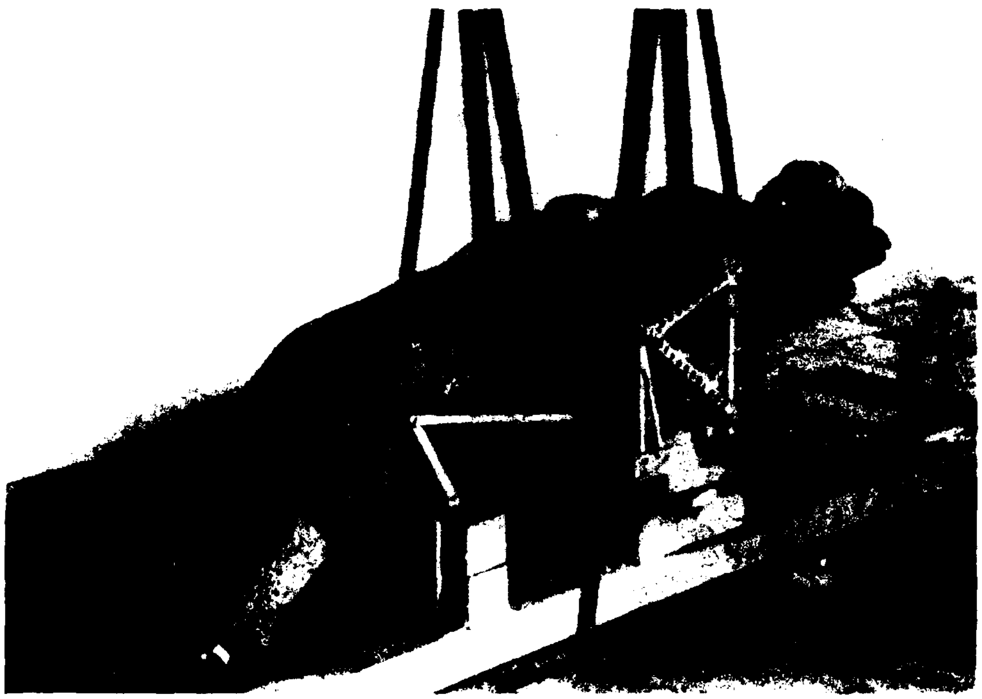


Fig. 46: The "Flop Back Seat" after supination. The seat itself moved forward and the seat back was tilted backwards to a horizontal position. The two spiral springs are expanded, and pull the seat back into its original position as soon as the G load decreases below 3 G. From Wiesehoefer (61), 1940.

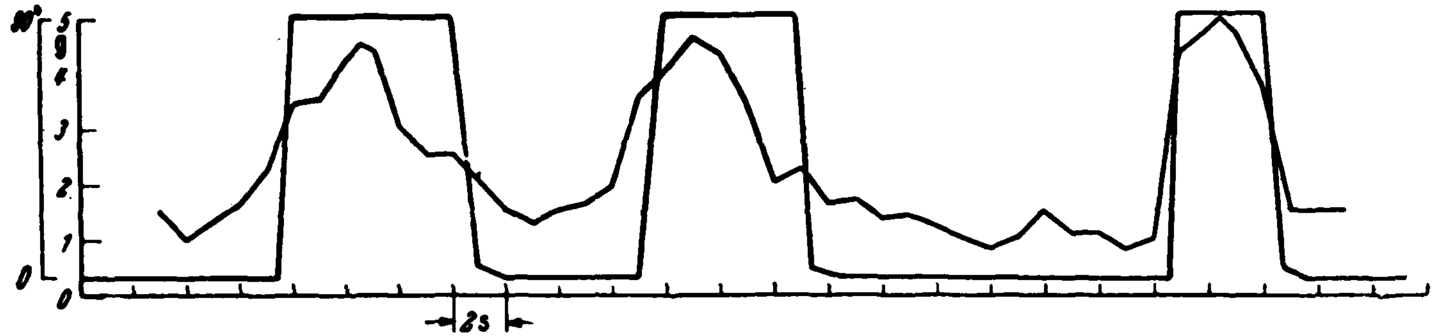


Fig.47 : Airborne recording of acceleration and tilting action of seat DVL-1. Triangular shaped curve: Acceleration. Trapezoid shaped curve: Tilting action; *Abscissa:* time; each division corresponds to 2 seconds. *Ordinate* left: tilting movement of seatback (0 - 90 degree); right: Acceleration in G units. It can be seen that at high rates of onset, as in the 3rd acceleration period, the seat back motion is somewhat retarded and reaches full supination at higher G levels as compared with lower rates of onset (1st and 2nd acceleration period). From Wiesehoefer (61), 1940.

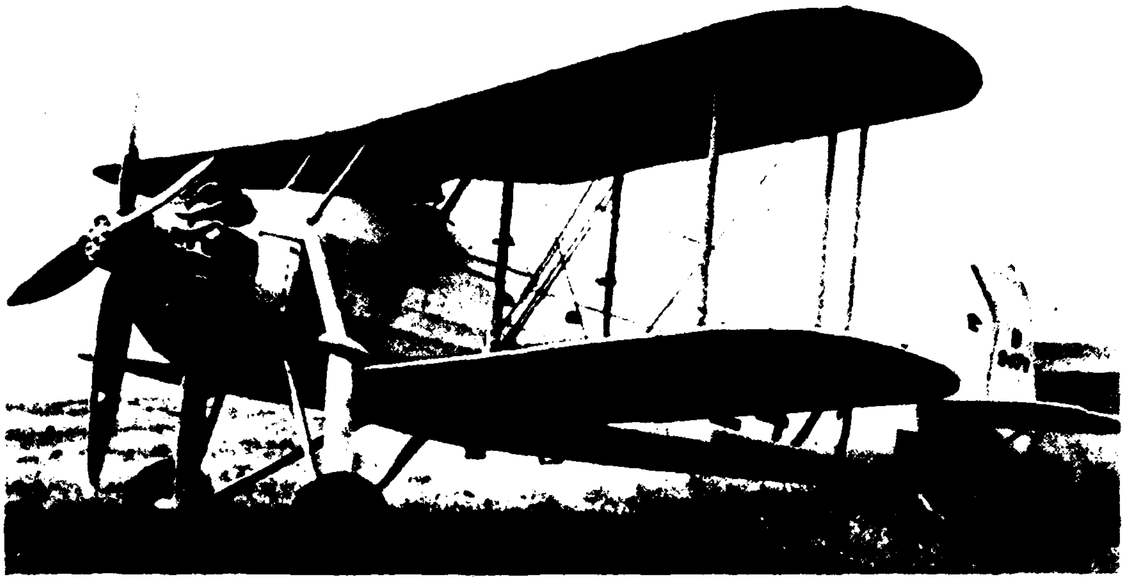


Fig.48: The biplane Dive bomber Heinkel He 50 used by the Experimental Institute of Aeronautics in Berlin-Adlershof for supine studies.

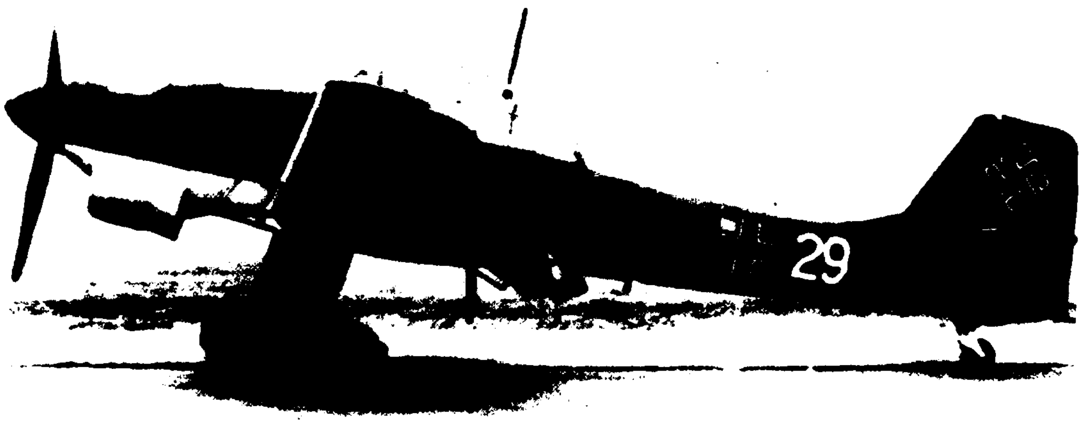


Fig.49: The dive bomber Junkers Ju 87. This aircraft was also used by Prof. S.Ruff from the German Experimental Institute of Aeronautics in Berlin-Adlershof for supine studies.

5. The Fairey Battle with a Fixed Semi-Supine Observer Seat Developed by W. K. Stewart

In 1940 the late Air Commodore William K. Stewart, then a flight Lieutenant MC, RAF, conducted airborne studies to evaluate the gain in G protection when reclined (45). He modified the observer seat of the light bomber Fairey Battle (Fig. 50) so as to support a wooden mock-up, which was inclined backwards at the greatest angle possible. Owing to structural limitations, this angle was approximately 45 degrees from the vertical. Figure 51 (upper part) shows this position and indicates the vertical distances between the 4th intercostal space and the eye and ankle respectively as well as the angles between thigh and spine, and leg and thigh. A series of runs were made with the maximum G obtainable which was 6-6.2 G. Most of the runs entailed accelerations of over 5 G for 10-20 seconds and a plateau of 6 G for 6-9 seconds. The investigator stated that these exposures would have blacked out the subjects if they would have been in the conventional position. In the investigated 45° position only one subject observed a very slight impairment of vision. Another series of runs was conducted with the subjects voluntarily placing themselves in the position illustrated in the central part of Figure 51, which is characterized by a spine angle of 50 degree from the vertical. In this position no subject experienced visual symptoms. The investigator concluded that in this position the average fighter pilot could sustain 6 to 6.5 G without impairment of vision. For higher G loads he deems necessary a position as depicted in the lower part of Figure 51, i.e. with a seatback angle of 65 degrees from the vertical, but recognizes the difficulties for the design and for the out-of-the-cockpit vision.

6. The Multi-Postural High-G Seat Assembly of the Naval Air Development Center

One of the most sophisticated reclining seat assemblies was developed by Gell (24) at the Naval Air Development Center (Fig. 52). This seat was incorporated in the rear cockpit of the twin-engine marine night fighter Grumman F7F-2N, and underwent airborne testing during 1952 (Fig. 53). The pivot points of this seat were near the subject's sternum. The modification of the electronic instrumentation was highly complex and sophisticated. Since no conventional controls were provided in the second cockpit, an autopilot (Type P-1K), integrated in the control system, maintained the aircraft in any desired magnetic heading and kept it stabilized in pitch and bank. Grip controls were located on the right and left arm rests of the tilting seat (Fig. 54). The right grip carried the usual autopilot controls, i.e. climb, dive, pitch center, left coordinated turn, right coordinated turn and turn center. The left grip controlled power increase and decrease, raising of the supine seat, lowering of the supine seat, and carried the microphone switch. Because the vertical gyro of the Autopilot (A.P.) limited the maneuverability of the aircraft to 70 degrees in climb and dive and 55 degrees left or right in roll, both with respect to the horizontal, control of the aircraft from the second cockpit was limited. A further limitation was caused by the A.P.'s controller which allowed only climbs or dives up to 60 degrees, and left and right banks up to 40 degrees, both with respect to the attitude existing when the A.P. was engaged. Since the supinated pilot could not normally see the horizon,

Fig. 50: The british light bomber Fairey Battle K 9289 used by W.K.Stewart for his studies of the supine position (45)

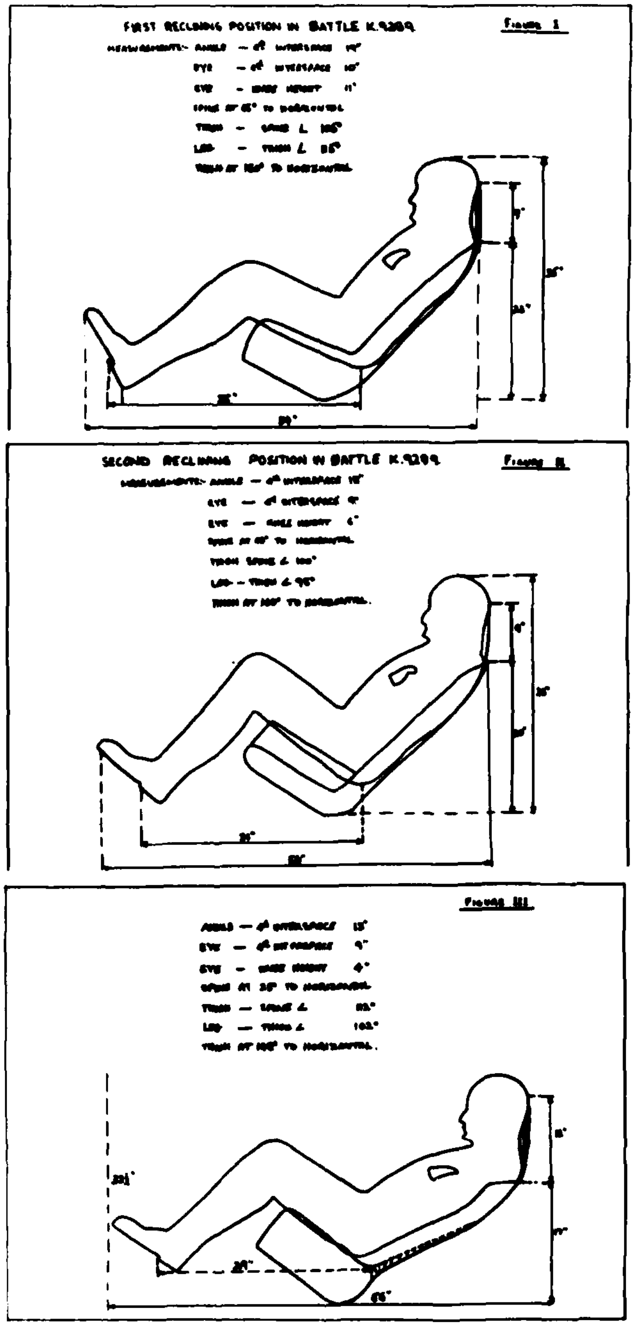


Fig. 51: Diagram of the 2 supine positions studied by W.K.Stewart in the Fairey Battle K9289 with a supination angle of 45 degree and 50 degree from the vertical. The position in the lowest picture, with an angle of 65 degree could not be studied because of the restricted room in the Fairey Battle.

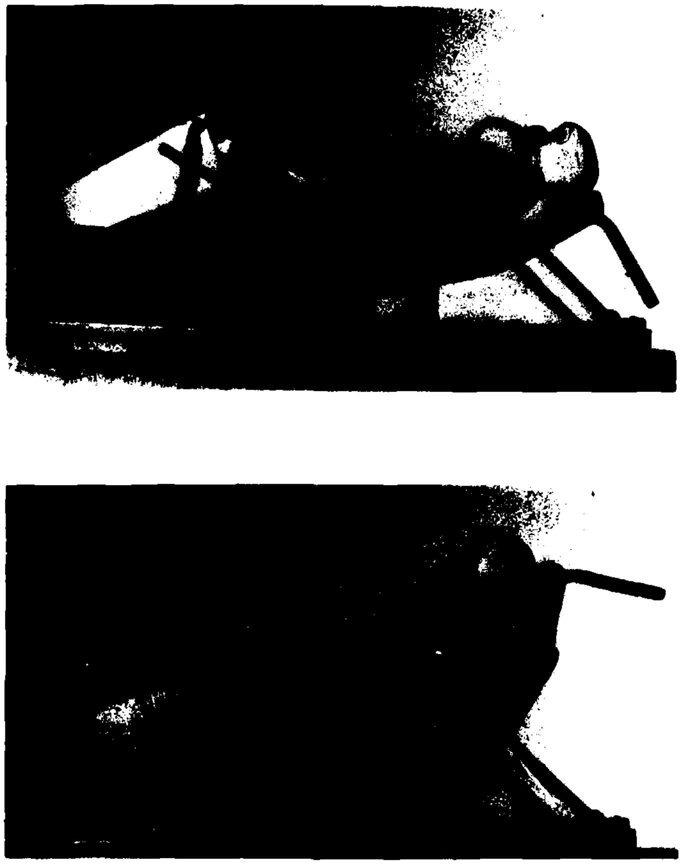


Fig. 52: The multi-postural supinating seat assembly of the Naval Air Development Center developed by Gell (61), 1949-1952. Above: In maximal supination; below: in conventional position. Between these *two* extreme positions a unlimited number of other postures could be achieved since the pilot could stop by handgrip control the hydraulically actuated supination action at any desired instant.

Fig.53 : The twin-engine marine night fighter aircraft Grumman F7F-2N with an elevated second cockpit. Gell (24) located in the second cockpit his supinating seat.

he had to fly by instruments. Therefore two instrument panels were installed which could be seen from the seated as well as supinated position (Fig.55 and 56).

After a preliminary evaluation by four pilot-subjects at the Naval Air Development Center, the aircraft F7F-2N with the supinating seat assembly was ferried to the Naval Air Test Center, Patuxent River, for a broader evaluation in which 23 subjects participated (36).

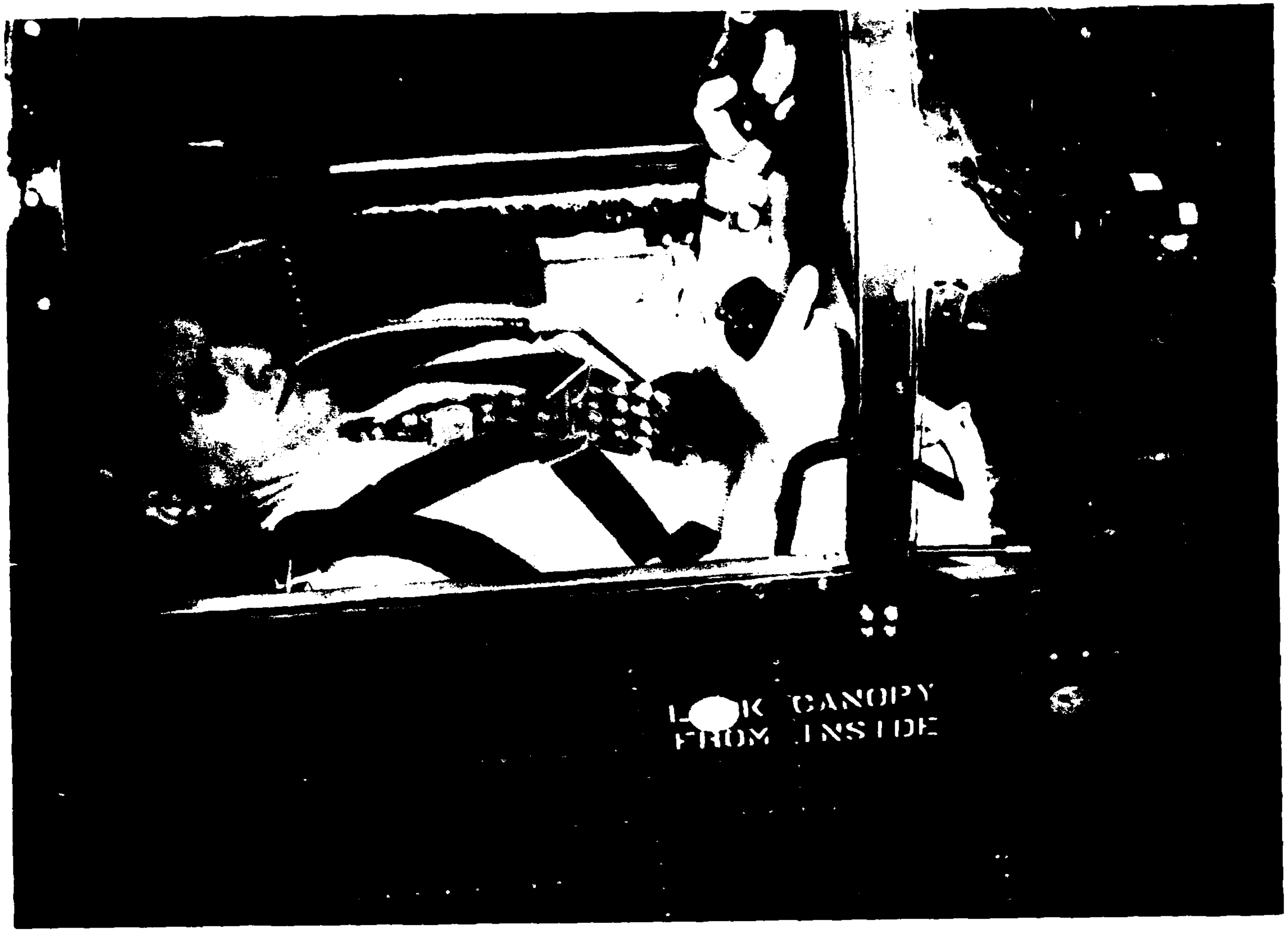
The unfavorable evaluation by a panel of test pilots is summarized as follows and is still true for all reclining seats of this type:

(1) Lack, or considerable impairment, of out-of-the-windshield vision while reclined.

(2) Poor visibility of displays, because the lower position of the head after reclining changes the visual azimuth and causes parallax, especially when reading such instruments as the gyro horizon. This was disturbing to a degree that several evaluators suggested that an instrument panel be provided which, by means of rotation synchronized with the seat supination, would maintain the directional relationship between eye and instruments.

A further and very important reason for the discontinuation of the development of the NADC seat, was that no documented need for high G protection had been established at that time. Just as the obsolesence of the Ju 87 in the early forties stopped the development of high G seats in Germany, the limited G capabilities of early jet aircraft in the fifties abolished the development of high G seats in the U.S. This is well illustrated by the way one of the evaluators answered the questionnaire's paragraph No. 9 ("Please give in detail any additional information that may be helpful in the future in the design of the seat for future type aircraft") and which can be considered as a Requiem for the NADC seat:

"It is difficult to visualize any airplane of the next few years that would require such a radical change as the supine seat. The G loads imposed now are likely to be less than in World War II. This is particularly so at altitudes where the airplane stalls long before the pilot suffers. At the risk of seeming unprogressive, I would offer the opinion that G suits should be improved (and made available), and that the supine seat should be filed and reconsidered at some later date". This is exactly what happened finally to the NADC seat -- it was filed.



SECOND COCKPIT - SEAT DOWN & OCCUPIED

Fig. 54: Subject in supinated position in the elevated rear cockpit of the F7F-2N aircraft. The hand-grips controled the craft by means of an autopilot. While supinated the subject had no out-of-the wind-shield vision and flew by instruments. From Gell (24), 1952.

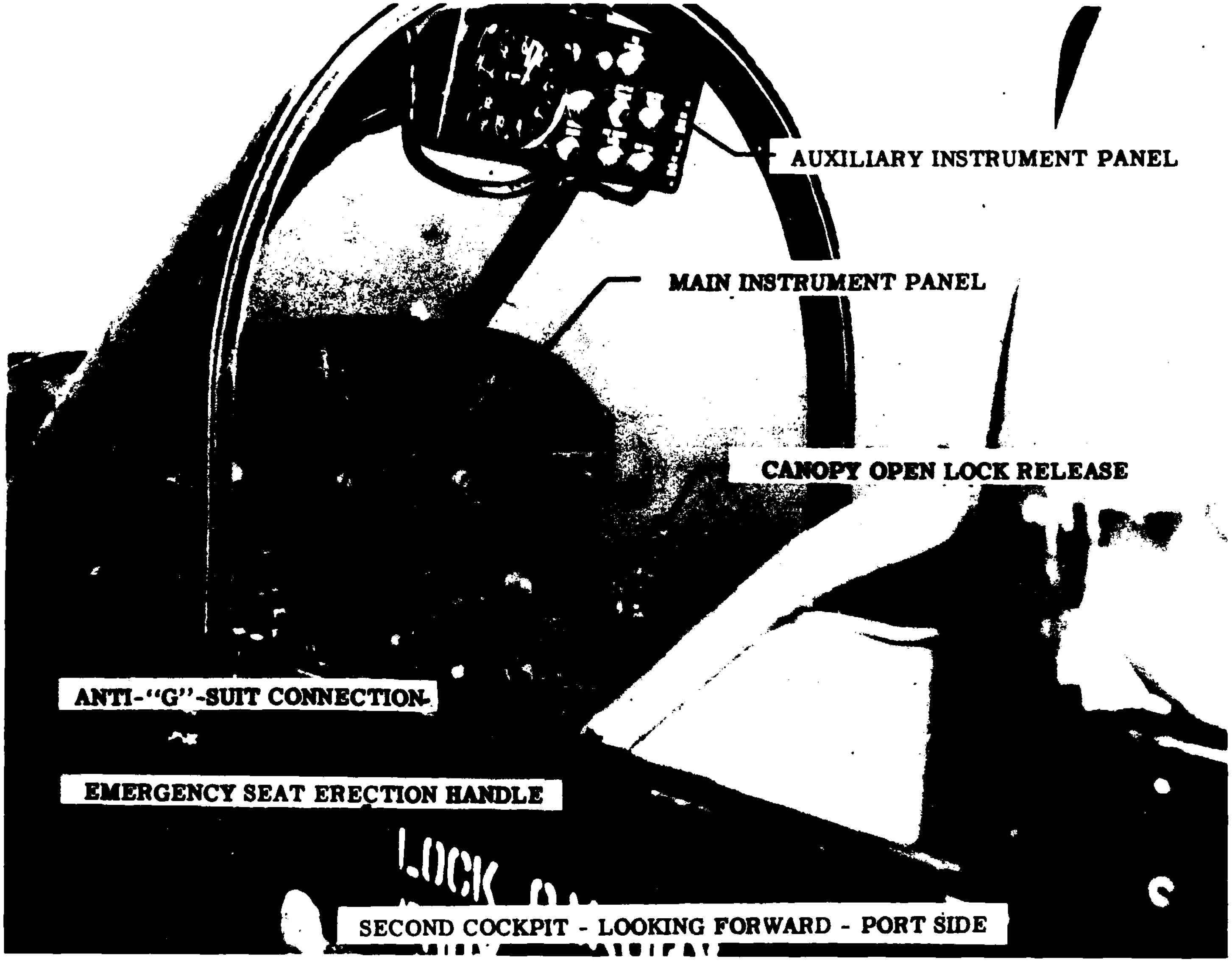


Fig. 55: The elevated rear cockpit of the F7F-2N with the seat in conventional position showing the main and the auxiliary instrument panel which could be seen from both positions. The lower position of the head after supination changed however the visual azimuth and caused parallax when reading such instruments as the gyro-horizon. From Gell (24), 1952.

Fig.56: Subject in the Gell seat in conventional position.

7. The PALE (Pelvis and Legs Elevating) Aircrew Seat

a. Background:

Early in the seventies it became known that the fighter aircraft of the eighties would be able to generate accelerations higher than the pilots could tolerate when seated in the conventional position. Thus, the author, who was involved in G-protection by supination since its early inception re-initiated the development of a supinating seat. Former supination efforts were short-lived because supination was achieved by reclining the seatback, which moved the heat downwards and backwards. As noted previously, the pilots did not accept the ensuing restricted out-of-the-cockpit vision and the poor visibility of the displays (parallax). In addition labyrinthine symptoms could be expected when the head moved within a changing G-field. Thus, it was a logical choice to develop a seat that achieves supination while the head stays stationary, i.e. a Pelvis and Legs Elevating (PALE) seat (Fig. 57).

To explore the optimal geometry of an articulated seat, several scale models were fabricated, including such an exotic one as that shown in Figure 58, which is based on the pantograph principle.

b. Centrifuge Testing:

At first a non-movable "Multi-posture Adjustable Centrifuge Test" (MACT) Seat was manufactured by a contractor*, and was installed in the NAVAIRDEVCEN 50 foot radius human centrifuge. This seat allowed support of the subject in a multitude of positions, i.e. seatback and legs could be located in any desired position. (Fig. 59)

Ten subjects were exposed to accelerations with seatback angles of 13°, 30°, 45°, 60° and 75°. The subjects were exposed both with the Anti-G Suit inflated and not inflated.

The G profile consisted of a 5-second rising time, 15 second plateau and 5 second decay time. For subjects who did not experience PLL at the 14G level, the plateau time was extended to 45 seconds.

The instrumentation included G registration in three axes, ECG, respiration rate and amplitude, earlobe oximetry, cinematographic and closed circuit TV observation, and PLL stimulus presentation and response time.

* The Wedge Company, Media, Pennsylvania

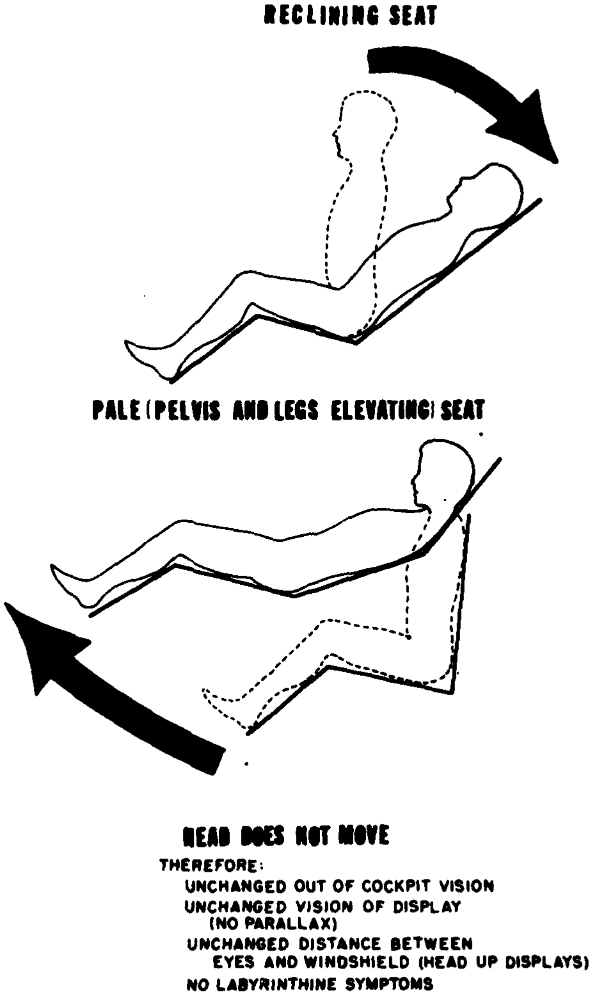
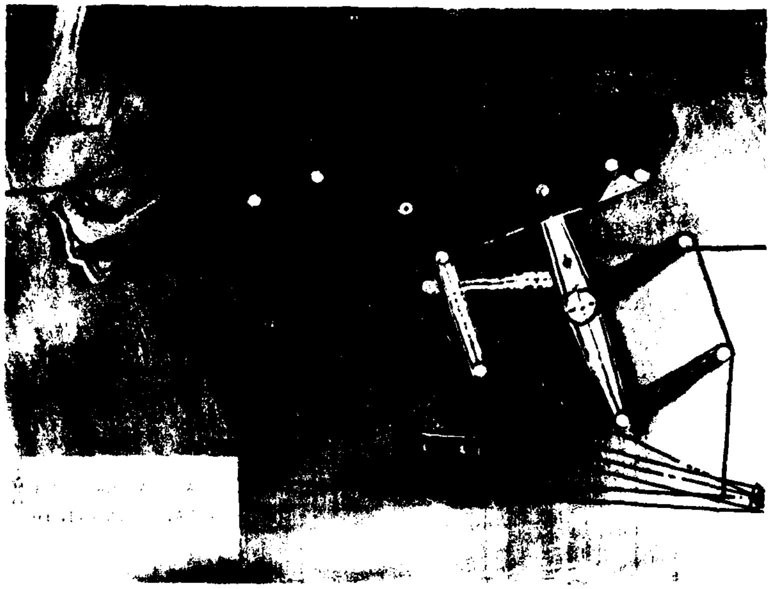


Fig. 57: The advantages of the PALE Seat versus the reclining seats



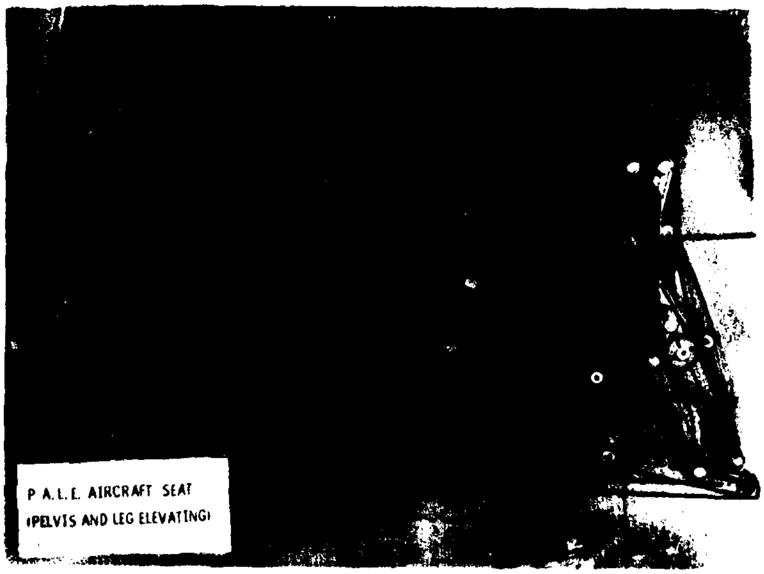


Fig. 58: A two-dimensional model of PALE design configuration PA 721. It is based upon the pantograph principle. Above: elevated position; below: conventional position.

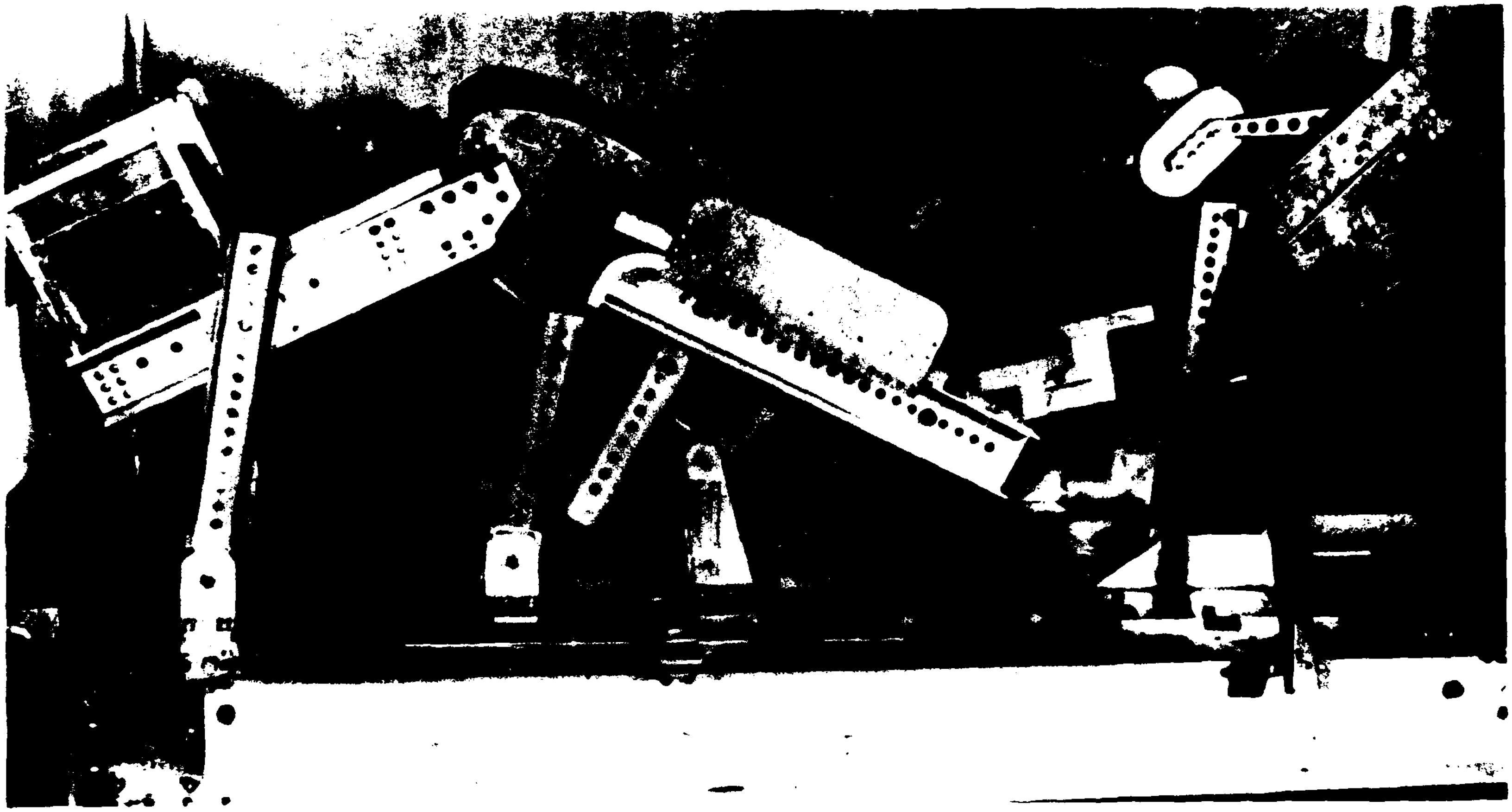


Fig.59: The MACT (Multi-Posture Adjustable Centrifuge Test) Seat. This seat allowed for support of the subject in a multitude of positions, i.e. seatback and legs could be located in any desired position. It served in centrifuge studies to establish the optimal configuration of the PALE seat.

Results

The results are depicted below.

Mean tolerance of 10 subjects:

Seat Back Angle	With Anti-G Suit Not Inflated	With Anti-G Suit Inflated
75°	8.2	10.5
60°	7.4	8.6
45°	6.3	7.8
30°	5.9	7.0
13°	5.6	6.9

The ten subjects were not selected on the base of a specially high G tolerance; in fact, three of the subjects had a known low G tolerance. The results indicated that at a 30 degree seatback angle (supinated from the vertical), there was no improvement of G tolerance. At 45 degrees a slight improvement was observed. At 60 degrees the improvement, which culminated at 75 degrees, became quite apparent. Beyond 75 degrees no further improvement is to be expected, in accordance with the results of centrifuge experiments conducted by Gell (25). Thus it was established that the optimal angle of the supine position is 75 degrees. The increase of tolerance in the PALE position has been anticipated since it is also in accordance with the hemostatic theory established in 1932 by von Diringshofen.

Another goal of this effort was to explore space-saving modifications of the original PALE assembly, which may allow for retrofit in existing aircraft configurations. These modifications consisted in the flection of the lower legs into a position parallel to the G vector, i.e. the lower legs are in a vertical position.

This LLV (Lower legs vertical) position, studied with a seatback angle of 75 degrees and 45 degrees, showed surprisingly the same protection and even, in some cases, a slightly superior protection than that obtained in the normal PALE position.

Another modification consisted in a quasi-fetal position; while maintaining a seatback angle of 75 degrees, the knees were elevated to the chin. Although this position is very unpractical, and the inflation of the Anti-G Suit is not feasible in this position, a mean value of 11.1 G was reached, which was the highest protection obtained.

	Not Inflated	Inflated
LLV with Seatback Angle 75^{o}	8.6	10.7
" " " " 45^{o}	6.5	7.9
Fetal Position (75^{o})	11.1	*

*Inflation of Anti-G suit is not feasible in this position.

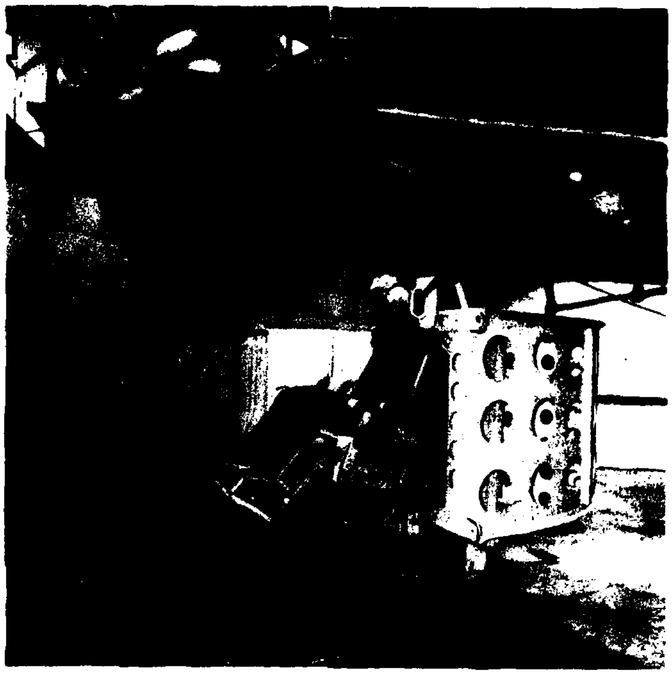
The 15-G rated moveable Centrifuge PALE Seat:

Based upon this preparatory research, a 15 G rated moveable Centrifuge PALE Seat was manufactured by the same Contractor*). This seat changed from the conventional position to the PALE position by rotating about an axis at the shoulder level (Fig. 60) in one second using hydraulic power. The rationale of the ensuing centrifuge experiments was to compare the G-protective qualities of the PALE seat in 3 different operational situations: (I) The pilot knows that high G maneuvers are imminent within a few seconds. He activates the elevation of the seat which has a duration of one second, and is already in the G-protective PALE position before he begins pulling G's. (II) The pilot has to pull high G's suddenly and without anticipation, such as to avoid an approaching missile. He will pull the handgrip and depress the elevation button at the same time, which means that he will be unprotected against an increasing G-load for one second before he reaches the protective PALE position. (III) Same situation as (II), but he omits to depress the elevation button. The elevation will be triggered automatically as soon as the acceleration reaches the 2.5 G_z value.

These operational situations were simulated on the 50-foot-radius centrifuge at the Naval Air Development Center. Using an onset rate (O.R.) of 3.5 G/s., 10 human volunteers were exposed to increasing G plateaus up to 14 G and up to 45 seconds duration employing peripheral light loss (PLL) as endpoint. The duration of the G plateau was 15 seconds. For subjects who did not experience PLL at the 14 G level, the plateau time was extended to 45 seconds. The M-1 maneuver was used in all runs.

For simulation of situation I, the subject was already at the beginning of the experiment located in the PALE position. Thus, he was already in the protective position before accelerations acted on him. Situation II was simulated by simultaneous activation of the centrifuge and the elevation of the PALE seat. Thus, the subject was exposed to an increasing G load up to 4.5 G for one second before elevation was completed. For simulation of situation III the seat elevation was triggered whenever the G load reached 2.5 G, i.e., 0.4 seconds after the onset of acceleration. Thus, the subject was unprotected for 1.4 seconds while the G load increased to 6 G.

* The Wedge Company, Media, Pennsylvania



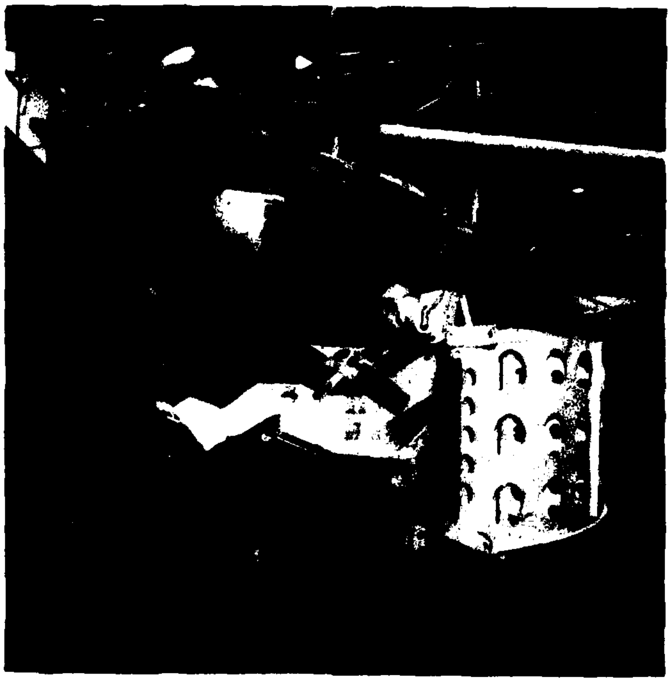


Fig.60: The PALE seat is removed from the gondola and mounted in an assembly ring.
Above: The Seat in conventional position
Below: The same seat in elevated (supine)position

The instrumentation included G registration in three axes, ECG, respiration rate and amplitude, closed circuit TV observation and recording, and PLL stimulus presentation and response time•recording.

Results:

The mean tolerance to PLL under the 3 operational situations is depicted below.

	With Anti-G Suit Not Inflated	Inflated
Situation I	8.2	10.5
Situation II	9.7	10.6
Situation III	10.5	11.5

Mean tolerance to G vectors in three simulated operational situations. (O.R. = 3.5 G/s., Endpoint: PLL)

Discussion:

The increased tolerance of the subjects who were exposed to G loads before reaching the protective PALE position can be explained by a more efficient mobilization of the reflectory Anti-G defense mechanisms. It would be premature, however, to select situation III as method of choice. Realistic simulation of repeated air combat maneuvers, as we plan for the future, will be necessary to select the optimal time of elevation.

The results of the PALE configurations with decreasing seatback angles are in accordance with the hemostatic theory (12) and with findings of other investigators (8,15,25, 38), although those mostly employed onset rates of less than 3.5 G/s. The fact that the space-saving LLV modification did not decrease the tolerance may be of importance for earlier retrofit of a PALE assembly in existing aircraft. The high tolerance in the fetal position (57) was anticipated for hemostatic reasons. It will be tested with lower seatback angles in the future, although its discomfort is considerable.

Conclusions:

(1) Experimentation with a PALE seat assembly which changes its position during centrifuge operation has confirmed the G protective qualities of this device.

(2) Efforts to retrofit modified PALE seat assemblies in experimental aircraft are highly desirable.

Centrifuge Experiments with the PALE Seat Simulating Air Combat Maneuvers

More recently these results were complemented by centrifuge experiments using profiles simulating air combat maneuvers (ACM). These experiments, conducted as part of a combined stresses study, included as variables extreme cockpit temperatures, buffet and noise. Four volunteers were exposed in the conventional, as well as in a 60 degree PALE position to a profile of six ACM's of 2½ minute duration with ten minutes intervals (Fig. 61). Each subject participated in 22 one-hour-sessions which equals a total centrifuge data collection time of 88 hours. The interaction of the various stressors and the bio-chemical and psychophysiologic findings are reported by J. S. Bowman (11). Here are only synthesized the G protection afforded by the PALE seat: (1) In the conventional position 27% of the sessions could not be completed because of extreme fatigue of the subjects. In the PALE position all sessions were completed. (2) In the conventional position, the subjects experienced temporary PLL in 25% of those sessions they were able to complete. In the PALE position PLL never occurred.

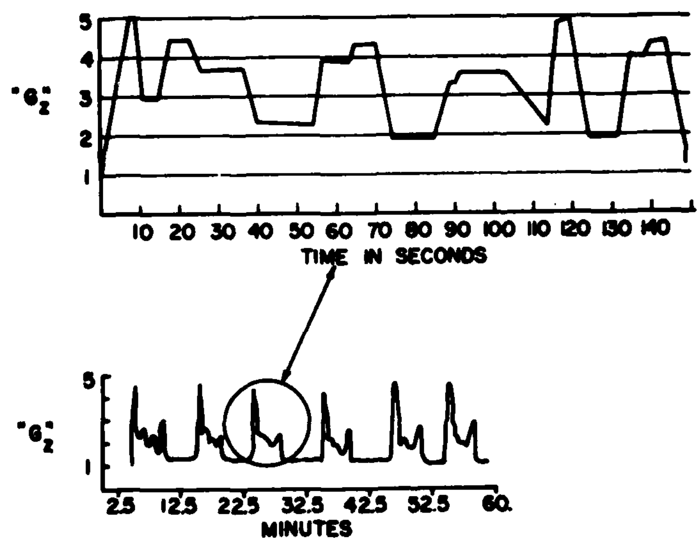


Fig. 61: Centrifuge G profile containing 6 G peaks within 2½ minutes. The profile is 6 times repeated.

Airborne Testing

The test bed selected was an experimental EVAR Helicopter (Sikorsky CH-53A), with a "3rd Pilot Station" in its cargo compartment. The pilot-in-command and the co-pilot were conventionally seated in the cockpit. In the "3rd pilot station" the conventional seat was replaced by a PALE configuration, built especially for these flights. The PALE seat was manufactured by the Workshops of the Naval Air Development Center. A stress analysis is contained in Technical Memorandum No. 60-TM-2000 of 28 February 1979, "Stress Analysis of a supine seat for installation in the CH-53A EVAR Helicopter at the Third Pilot Station." Certification No. 717 of 18 April 1979 authorized the PALE seat for test flights. It allowed for control of the aircraft from a 55 degree seatback position as well as from a 70 degree seatback position (both from the vertical). The modified control column and the conventional rudder pedals could be easily operated from both positions. Two TV cameras, one mounted on the aircraft's nose, the other under its belly, provided visual displays for the experimental pilot and for the test coordinator, whose station was situated behind the "3rd pilot station."

Three experimental pilots (E.P.) with considerable fixed-wing and rotary-wing experience participated in the test flights. After the command pilot engaged the "3rd pilot station," each E.P. took command of the aircraft for 30 minutes in the 55 degree seatback position, and for the same period of time in the 70 degree position. The command pilot requested the E.P. to perform maneuvers of increasing complexity, beginning with straight level flight and including turns of up to 50 degrees bank. The pilot in command evaluated the performance of the E.P. by completing questionnaires and in oral debriefings. Also the E.P. completed questionnaires indicating subjective findings. The entire on-board conversations were stored on tape and evaluated. (Fig.87,Fig.88)

Results:

(1) All E.P.'s performed normally "as if they had flown all their life lying on the back."

(2) Surprisingly, no adaptation time to the unusual supine position was needed.

(3) The E.P.'s found both the 55 degree and the 70 degree seatback positions very comfortable. Surprisingly, however, they favored the 70 degree position as most comfortable. To quote: "It was so comfortable, I had to watch out not to fall asleep."

Discussion:

The G protective capabilities of the PALE seat were proven previously in 4 series of centrifuge experiments. Thus, it was the objective of this airborne evaluation to show that a modern aircraft can be flown reliably and comfortably from a supine position.

Fig.62: The author in supine position in the "3rd Pilot Station" of the experimental aircraft CH-53 A EVAR. The control column had been prolonged for being in the reach of the supinated pilot.

PROJECT PALE IED GC-336
"Preliminary Airborne Testing of a G-protective Supine Seat System (PALE)"

Questionnaire
for
Command Pilot

PALE TEST FLIGHT # 2

Date: 20 April 1979
Time:
Command Pilot: LT USN Dave Purington

Seatback Angle: ☐ 55°
☒ 70°

Experimental pilot's name: ☐ James Boschma
☐ John I.O'Sullivan
☒ Jay C. Lillie

1. For how many minutes did you relinquish the command to the experimental pilot(E.P) ?
23 MIN

2. How did the E.P. perform the following maneuvers: (rating 1-4, 1 being the best)

a. Straight level 1

b. Straight level right and left turns 1

c. Climbing turns NA

d. Descending turns NA

e. Steep turns 1

f. Others ______

3. Was the E.P. able to perform correctly the above mentioned maneuvers immediately after taking command, or did he need some time to adjust to the unusual supine position?

☒ immediately ☐ needed "adjusting time" of ______ minutes

4. How often did you relinquish the command to the E.P.

ONCE

5. Did you have to override the E.P.? ☐ yes ☒ no
If so how often and at what maneuvers: ______

5. Additional remarks (if any):

OUTSTANDING, SMOOTH CONTROL

SIGNATURE: DA Purington DATE: 14 MAY 79

Fig.63: Questionnaire for the Command Pilot evaluating the performance of the Experimental Pilot in the PALE seat in the flight of April 20,1979

PROJECT PALE IED GC-336
"Preliminary Airborne Testing of a G-protective Supine Seat System (PALE)"

Questionnaire
for
Experimental Pilot (E.P.)

PALE TEST FLIGHT # 2

Date: 20 April 1979
Time:

Seatback Angle: ☐ 55°
☒ 70°

Command Pilot: Dave Purington, LT USN E.P.: Maj J.C. Lillie USMC

1. Did the supine position cause discomfort or pressure points? ☐ yes ☒ no
If so, please elaborate:

2. Could you perform the requested maneuvers immediately after taking command or did you need some "adjusting time" for the unusual supine position?

☐ immediately ☒ needed "adjusting time" of 1 minutes

3. Which maneuvers, if any, were for you difficult to perform:
see previous flight

4. Did you request to be released from the command of the aircraft at any time?
☐ yes ☒ no

If yes, under what circumstances?

5. How many hours did you fly as Pilot-in-Command in fixed wing aircraft? ...3500...
" " " " " " " Co-pilot " " " " ...500...
" " " " " " " Pilot-in-Command in rotary wing aircraft? ...650...
" " " " " " " Co-pilot " " " " ...100...
How many hours did you fly previously in the "Third Pilot Station" ? ...-0-...

6. Your age? 38...years.

7. Additional remarks, observations, or suggestions (if any):
The PALE SEAT is very comfortable in the 55° or 70° position. With optimum cockpit design of controls it would be great. It was so comfortable I had to watch out not to fall asleep

SIGNATURE: J.C. Lillie DATE: 27 April 79

Fig.64: Questionnaire for the Experimental Pilot evaluating the PALE seat in the flight of April 20, 1979

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CONCLUSION

The PALE seat, as compared with other tilting seats described in this report, has the definite advantages of:

(1) out-of-the-cockpit vision remains unchanged
(2) vision of displays is maintained
(3) the distance between eyes and windshield remains constant
(4) no labyrinthine symptoms are produced, since the head does not move.

The author presented the PALE seat for the first time on 21 September 1972 at the 20th International Congress of Aviation and Space Medicine in Nice, France (51). The PALE seat was also described on March 1973 at the Triservice Review of Research on Sustained Acceleration, which was held at the 113th Meeting of the Joint Medical Research Conference of the Directorate of Defense Research and Engineering, the Pentagon, Washington, DC (53).

On 30 July 1974, US Patent Number 3,826,434 entitled "Pelvis and Legs Elevating G-protective Crew Seat" was granted to the author, (55).

The on-going Testing and Centrifuge experiments, including airborne testing, were reported at the 44th, 46th, 47th and 50th Scientific Meeting of the Aerospace Medical Association in 1973 (52), 1975 (56), 1976 (57), and 1979 (58), respectively.

It is unfortunate that these and numerous other publication efforts did not result in the incorporation of the PALE seat in operational fighter aircraft. The urgency to provide Fighter aircraft with articulated seats can not be overemphasized.

It is hoped that a potential adversary does not build the PALE seat first. A squadron equipped with the PALE seat would have a spectacular advantage in air combat situations, and could literally fly circles around their adversaries.

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